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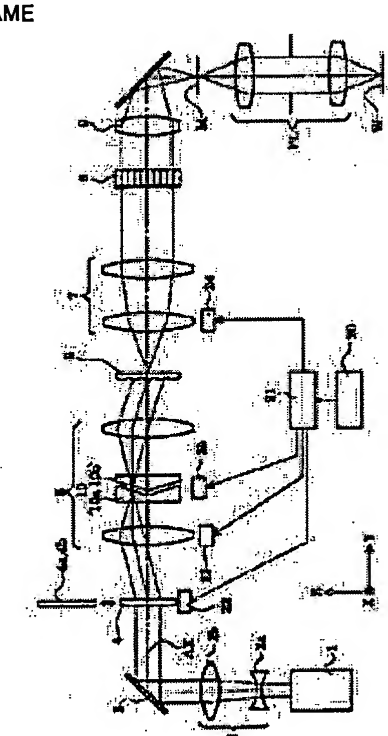
(54) OPTICAL ILLUMINATION EQUIPMENT AND ALIGNER EQUIPPED WITH THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide optical illumination equipment which can realize different lighting conditions in two orthogonal directions on the surface to be irradiated.
SOLUTION: In this optical illumination equipment, a variable power optical system (7), which is used for similarly changing the whole size of second multiple light sources, is arranged in the optical path between a first optical integrator (6) which is used for forming first multiple light sources, based on the luminous flux from a light source means (1) and a second integrator (8), which is used for forming the second multiple light sources, the number of which is larger than that of the first multiple light sources, based on the luminous fluxes from the first multiple light sources. This illumination equipment is also provided with an aspect ratio changing element (10), which changes the aspect ratio of the incident luminous flux to the first optical integrator (6) for changing the incident angle of the luminous flux in the prescribed direction.



CLAIMS

[Claim(s)]
[Claim 1]The 1st optical integrator for forming the 1st a large number light source based on light flux from a light source means, In an illumination optical device which is provided with the 2nd optical integrator for forming many 2nd a large number light sources more based on light flux from said 1st a large number light source, and illuminates an irradiated plane by light flux from said 2nd a large number light source, A variable power optical system for being arranged in an optical path between said 1st optical integrator and said 2nd optical integrator, and changing a size of said whole 2nd a large number light source in similarity, An illumination optical device provided with an aspect ratio change element which changes an aspect ratio of said incoming beam in order to change the degree of incidence angle along a prescribed direction of an incoming beam to said 1st optical integrator.
[Claim 2]In an illumination optical device provided with a light guide optical system for leading light flux from an optical integrator and this optical integrator for forming many light sources based on light flux from a light source means to an irradiated plane, A light flux sensing element for changing into light flux which has light flux which has predetermined sectional shape for light flux from said light source means, or predetermined light intensity distribution, It is arranged in an optical path between said light flux sensing element and said optical integrator, An illumination optical device provided with an aspect ratio change element which changes an aspect ratio of said incoming beam in order to change the degree of incidence angle along a prescribed direction of an incoming beam to said optical integrator.
[Claim 3]The illumination optical device according to claim 1 or 2, wherein said aspect ratio change element is constituted pivotable considering an optic axis as a center.
[Claim 4]The 1st aspect ratio change element for said aspect ratio change element to change the degree of incidence angle which met in the 1st direction of an incoming beam to said optical integrator or said 1st optical integrator, The illumination optical device according to claim 1 or 2 having the 2nd aspect ratio change element for changing the degree of incidence angle which met in said 1st direction of an incoming beam to said optical integrator or said 1st optical integrator, and the 2nd direction that intersects perpendicularly.
[Claim 5]The 1st prism with which said aspect ratio change element has a refracting interface of a concave section along said prescribed direction, It has the 2nd prism that has a refracting interface of said concave section of this 1st prism, and a refracting interface of a convex section formed complementarily, An illumination optical device given in any 1 clause of Claims 1-4, wherein either is constituted movable in accordance with an optic axis at least among said 1st prism and said 2nd prism.
[Claim 6]The illumination optical device according to claim 5, wherein said concave section of said 1st prism has V character-like form.
[Claim 7]An exposure device provided with an illumination optical device given in any 1 clause of Claims 1-6, and a projection optical system for carrying out projection exposure of the pattern of a mask arranged in said irradiated plane to a photosensitive substrate.
[Claim 8]A manufacturing method of a micro device including an exposure process which exposes a pattern of said mask on said photosensitive substrate with the exposure device according to claim 7, and a developing process which develops said photosensitive substrate exposed by said exposure process.
[Claim 9]In an illumination optical device which it had, an illumination-light study system which illuminates an object to be illuminated said illumination-light study system, Have a variable means which makes variable either [at least] a size of illumination light in a pupil of this illumination-light study system, or the form, and said variable means, The 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An illumination optical device having the 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and a variable power optical system which makes a size of said illumination light variable.
[Claim 10]The illumination optical device according to claim 9, wherein said illumination-light study system is provided with an optical form conversion method which leads illumination light which changed into light flux form of a request of form of said illumination light, and was changed into light flux form of this request to said variable means.
[Claim 11]The illumination optical device comprising according to claim 10:
The 1st diffracted-light study component from which said optical form conversion method changes form of said illumination light into the 1st light flux form.
The 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes form of said illumination light into the 2nd light flux form.

[Claim 12]An illumination optical device given in any 1 clause of Claims 9-11, wherein said illumination-light study system is provided with an optical integrator which is arranged in an optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[Claim 13]An exposure method which exposes a pattern of a mask to a photosensitive substrate, comprising:
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system.

A zona-orbicularis operation grant process that said Lighting Sub-Division process gives an operation which changes illumination light in a pupil of said illumination-light study system in the shape of zona orbicularis including a projection process of projecting a pattern image of said mask on said photosensitive substrate.
The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system.
The 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.

[Claim 14]The exposure method according to claim 13, wherein said Lighting Sub-Division process includes further a variable power process of making a size of said illumination light variable.
[Claim 15]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, The 1st displacement process which displaces illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system in a pupil of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and a variable power process of making a size of said illumination light variable.
[Claim 16]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, Lighting Sub-Division conditions over said mask including a change process to change said change process, A selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system is included, A zona-orbicularis operation grant process that said 1st setting-out process gives an operation which changes illumination light in a pupil of said illumination-light study system in the shape of zona orbicularis, The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, Including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, said 2nd setting-out process, The 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, and said optic axis, and intersects said 1st direction, An exposure method including a variable power process of making a size of said illumination light variable.
[Claim 17]An illumination optical device comprising provided with an illumination-light study system which illuminates an object to be illuminated:
A zona-orbicularis ratio variable means which gives an operation changed in the shape of [in which said illumination-light study system equips with a variable means which makes variable either / at least / a size of illumination light in a pupil of this illumination-light study system, or the form, and said variable means has a zona-orbicularis ratio of a request of said illumination light] zona orbicularis.
The 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system.

[Claim 18]The illumination optical device according to claim 17, wherein said variable means has a variable power optical system which makes a size of said illumination light variable.
[Claim 19]The illumination optical device according to claim 17 or 18 having the 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that said optic axis and said variable means cross at right angles, and intersects said 1st direction.
[Claim 20]An illumination optical device given in any 1 clause of Claims 17-19, wherein said illumination-light study system is provided with an optical form conversion method which leads illumination light which changed into light flux form of a request of form of said illumination light, and was changed into light flux form of this request to said variable means.
[Claim 21]The illumination optical device according to claim 20, wherein said optical form conversion method has the 1st diffracted-light study component which changes form of said illumination light into the 1st light flux form, and the 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes form of said illumination light into the 2nd light flux form.
[Claim 22]An illumination optical device given in any 1 clause of Claims 17-21, wherein said illumination-light study system is provided with an optical integrator which is arranged in an optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[Claim 23]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, Either [at least] a size of illumination light in a pupil of said illumination-light study system, or the form including a variable process made variable the aforementioned variable process, zona orbicularis which gives an operation changed in the shape of [with a zona-orbicularis ratio of a request of said illumination light] zona orbicularis — a ratio — an exposure method including a variable process and the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system.
[Claim 24]The exposure method according to claim 23, wherein the aforementioned variable process includes further a variable power

process of making a size of said illumination light variable.
[Claim 25]The exposure method according to claim 23 or 24, wherein the aforementioned variable process includes further the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
[Claim 26]An exposure method given in any 1 clause of Claims 23-25, wherein said Lighting Sub-Division process includes further an optical form converting process which changes form of said illumination light into desired light flux form in front of the aforementioned variable process.
[Claim 27]The 1st diffraction process from which said optical form converting process changes form of said illumination light into the 1st light flux form using the 1st diffracted-light study component, The exposure method according to claim 26 including the 2nd diffraction process of changing form of said illumination light into the 2nd light flux form using said 1st diffracted-light study component and the 2nd diffracted-light study component provided exchangeable.
[Claim 28]An exposure method given in any 1 clause of Claims 23-27, wherein said Lighting Sub-Division process includes a uniform illumination process of using an optical integrator and illuminating said object to be illuminated uniformly after the aforementioned variable process.
[Claim 29]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, Lighting Sub-Division conditions over said mask including a change process to change said change process, A selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system is included, zona orbicularis which gives an operation changed in the shape of [in which said 1st setting-out process has a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis — a ratio — with a variable process. An exposure method, wherein said 2nd setting-out process includes a displacement process which displaces said illumination light symmetrically on both sides of said optic axis along a prescribed direction which intersects perpendicularly with an optic axis of said illumination-light study system, and a variable power process of making a size of said illumination light variable, including a variable power process of making a size of said illumination light variable.
[Claim 30]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, zona orbicularis which gives an operation changed in the shape of [with a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis — a ratio — with a variable process. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
[Claim 31]The Lighting Sub-Division process of illuminating said mask via an illumination-light study system in an exposure method which exposes a pattern of a mask to a photosensitive substrate, A pattern image of said mask including a projection process projected on said photosensitive substrate said Lighting Sub-Division process, Lighting Sub-Division conditions over said mask including a change process to change said change process, The 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system, And at least one of the 3rd setting-out processes of setting up the 3rd Lighting Sub-Division conditions of said illumination-light study system, including a selection process to choose said 1st setting-out process, zona orbicularis which gives an operation changed in the shape of [with a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis — a ratio — with a variable process. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, Including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, said 2nd setting-out process, zona orbicularis which gives an operation changed in the shape of [with a zona-orbicularis ratio of a request of said illumination light] zona orbicularis — a ratio — said 3rd setting-out process including a variable process and a variable power process of making a size of said illumination light variable, The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and a variable power process of making a size of said illumination light variable.
[Claim 32]An exposure device comprising:
Claims 9-12 for illuminating a mask as said object to be illuminated, and an illumination optical device given in any 1 clause of Claims 17-22.
A projection optical system for projecting a pattern image of said mask on a photosensitive substrate.

[Claim 33]A manufacturing method of a micro device characterized by comprising the following.
An exposure process which exposes a pattern of said mask to said photosensitive substrate using the exposure device according to claim 32.
A developing process which develops said photosensitive substrate exposed by said exposure process.

[Claim 34]A manufacturing method of a micro device characterized by comprising the following.
An exposure process which exposes a pattern of said mask to said photosensitive substrate using an exposure method given in any 1

clause of Claims 13-16 and Claims 23-31.
A developing process which develops said photosensitive substrate exposed by said exposure process.

[Claim 35]An exposure method which exposes a pattern of a mask to a photosensitive substrate, comprising:
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system.
A projection process of projecting a pattern image of said mask on said photosensitive substrate using a projection optical system.
An exposing condition setting-out process of setting a sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95 when said Lighting Sub-Division process performing said projection process including a measurement step which measures the optical property of said projection optical system.
A measurement condition setting-out process of setting a sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 when performing said measurement step.

[Claim 36]Including further a scanning process to which said mask and said photosensitive substrate are moved along a scanning direction when performing said projection process said Lighting Sub-Division process, The exposure method according to claim 35 characterized by filling a relation of 0.05<Ls/Ll<0.7 when setting the length Ls of the transverse direction of said illuminated field, and the length of a longitudinal direction of said illuminated field to Ll including a process of forming an illuminated field of rectangular shape which has a longitudinal direction and the transverse direction on said mask.
[Claim 37]An exposure device which exposes a pattern of a mask to a photosensitive substrate, comprising:
An illumination-light study system which illuminates said mask.
Have a projection optical system which projects a pattern image of said mask on said photosensitive substrate, and said illumination-light study system, A Lighting Sub-Division conditioning means to set a sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95 when exposing a pattern of said mask to said photosensitive substrate, and to set a sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 when [, in which the optical property of said projection optical system is measured] measuring.

[Claim 38]When exposing a pattern of said mask to said photosensitive substrate, it has further a scanning means to which said mask and said photosensitive substrate are moved along a scanning direction, When setting to Ll the length of a longitudinal direction of said illuminated field which sets to Ls the length of the transverse direction of said illuminated field formed in said mask of said illumination-light study system, and is formed in said mask of said illumination-light study system, The exposure device according to claim 37 filling a relation of 0.05<Ls/Ll<0.7.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the suitable illumination optical device for the exposure device for manufacturing micro devices, such as a semiconductor device, an image sensor, a liquid crystal display element, and a thin film magnetic head, by a lithography step especially about the exposure device provided with the illumination optical device and this illumination optical device.
[0002]
[Description of the Prior Art]In this kind of typical exposure device, the light flux ejected from the light source forms the secondary light source as the substantial surface light source which consists of many light sources via the fly eye lens as an optical integrator. The light flux from a secondary light source enters into a condenser lens, after being restricted via the aperture diaphragm arranged near the backside focal plane of a fly eye lens.
[0003]The light flux condensed with the condenser lens illuminates in superposition the mask in which the predetermined pattern was formed. Image formation of the light which penetrated the pattern of the mask is carried out on a wafer via a projection optical system. In this way, on a wafer, projection exposure (transfer) of the mask pattern is carried out. The pattern formed in the mask is integrated highly and it is indispensable to transfer this minute pattern correctly on a wafer to acquire uniform illuminance distribution on a wafer.
[0004]
[Problem to be solved by the invention]Then, the secondary light source of a circle configuration is formed in the backside focal plane of a fly eye lens, and the technology of changing the size and changing the coherency sigma of Lighting Sub-Division (sigma value = the pupil diameter of the diameter of an aperture diaphragm / projection optical system or the incidence side numerical aperture of the number of injection side openings / projection optical system of a sigma value = illumination-light study system) attracts attention. The secondary light source of the shape of zona orbicularis or the shape of 4 poles is formed in the backside focal plane of a fly eye lens, and the technology of raising the depth of focus and resolution of a projection optical system attracts attention.
[0005]Also however, in usual circular Lighting Sub-Division based on the secondary light source of a circle configuration at the above conventional technologies, The sectional shape of the light flux which enters into one on the mask which is an irradiated plane is related for [on a mask] the two way types which intersect perpendicularly, and the case of the deformation illumination (4 very zona-orbicularis Lighting Sub-Division and Lighting Sub-Division) based on the secondary light source of the shape of zona orbicularis or the shape of 4 poles also has it in the same physical relationship. If it puts in another way, Lighting Sub-Division conditions are the same for [with which it intersects perpendicularly on an irradiated plane in conventional technology] two way types. As a result, when a mask pattern has directivity, the Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on a mask cannot be realized. By the way, in recent years, it is anxious for the ability of the optical performance of a projection optical system to be simultaneously checked [transferring the pattern of a mask correctly under relevant Lighting Sub-Division conditions, and] with high degree of accuracy when transferring the pattern of a mask correctly.
[0006]This invention is made in view of above-mentioned SUBJECT, and is a thing.
The purpose is to provide the exposure device provided with the illumination optical device and this illumination optical device which can realize Lighting Sub-Division conditions which are mutually different for the two way types with which ** intersects perpendicularly.
An object of this invention is to provide the manufacturing method of the micro device which can manufacture a micro device good under good Lighting Sub-Division conditions using the exposure device which can set up the Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on the mask which has directivity in a pattern. This invention can transfer the pattern of a mask correctly under relevant Lighting Sub-Division conditions, and also makes it the purpose simultaneously to provide the exposure device which can check the optical performance of a projection optical system with high degree of accuracy, an exposure method, etc. when transferring the pattern of a mask correctly.
[0007]
[Means for solving problem]In order to solve said SUBJECT, in the 1st invention of this invention. The 1st optical integrator for forming the 1st a large number light source based on the light flux from a light source means, In the illumination optical device which is provided with the 2nd optical integrator for forming many 2nd a large number light sources more based on the light flux from said 1st a large number light source, and illuminates an irradiated plane by the light flux from said 2nd a large number light source, The variable power optical system for being arranged in the optical path between said 1st optical integrator and said 2nd optical integrator, and changing the size of said whole 2nd a large number light source in similarity, In order to change the degree of incidence angle along the prescribed direction of the incoming beam to said 1st optical integrator, an illumination optical device provided with the aspect ratio change element which changes the aspect ratio of said incoming beam is provided.
[0008]The optical integrator for forming many light sources in the 2nd invention of this invention based on the light flux from a light source means, In the illumination optical device provided with the light guide optical system for leading the light flux from this optical integrator to an irradiated plane, The light flux sensing element for changing into the light flux which has the light flux which has

predetermined sectional shape for the light flux from said light source means, or predetermined light intensity distribution, It is arranged in the optical path between said light flux sensing element and said optical integrator, In order to change the degree of incidence angle along the prescribed direction of the incoming beam to said optical integrator, an illumination optical device provided with the aspect ratio change element which changes the aspect ratio of said incoming beam is provided.
[0009]According to the desirable mode of the 1st invention or the 2nd invention, said aspect ratio change element is constituted pivotable considering the optic axis as a center. Or the 1st aspect ratio change element for said aspect ratio change element to change the degree of incidence angle which met in the 1st direction of the incoming beam to said optical integrator or said 1st optical integrator, It is preferred to have the 2nd aspect ratio change element for changing the degree of incidence angle which met in said 1st direction of the incoming beam to said optical integrator or said 1st optical integrator and the 2nd direction that intersects perpendicularly.
[0010]According to the desirable mode of the 1st invention, said aspect ratio change element, It has the 1st prism that has a refracting interface of a concave section along said prescribed direction, and the 2nd prism that has a refracting interface of said concave section of this 1st prism, and a refracting interface of a convex section formed complementarily, Either is constituted movable in accordance with an optic axis at least among said 1st prism and said 2nd prism. In this case, as for said concave section of said 1st prism, it is preferred to have V character-like form.
[0011]In the 3rd invention of this invention, an exposure device provided with an illumination optical device of the 1st invention or the 2nd invention and a projection optical system for carrying out projection exposure of the pattern of a mask arranged in said irradiated plane to a photosensitive substrate is provided.
[0012]In the 4th invention of this invention, a manufacturing method of a micro device including an exposure process which exposes a pattern of said mask on said photosensitive substrate with an exposure device of the 3rd invention, and a developing process which develops said photosensitive substrate exposed by said exposure process is provided.
[0013]In the 5th invention of this invention, an illumination-light study system which illuminates an object to be illuminated in an illumination optical device which it had said illumination-light study system, Have a variable means which makes variable either [at least] a size of illumination light in a pupil of this illumination-light study system, or the form, and said variable means, The 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An illumination optical device having the 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and a variable power optical system which makes a size of said illumination light variable is provided.
[0014]According to the desirable mode of the 5th invention, said illumination-light study system is provided with the optical form conversion method which leads the illumination light which changed into the light flux form of the request of the form of said illumination light, and was changed into the light flux form of this request to said variable means. In this case, as for said optical form conversion method, it is preferred to have the 1st diffracted-light study component which changes the form of said illumination light into the 1st light flux form, and the 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes the form of said illumination light into the 2nd light flux form. As for said illumination-light study system, it is preferred to have the optical integrator which is arranged in the optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[0015]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 6th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, The zona-orbicularis operation grant process of giving the operation which changes the illumination light in the pupil of said illumination-light study system in the shape of zona orbicularis, The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction is provided. In this case, as for said Lighting Sub-Division process, it is preferred to include further the variable power process of making the size of said illumination light variable.
[0016]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 7th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, The 1st displacement process which displaces the illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system in the pupil of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and the variable power process of making the size of said illumination light variable is provided.
[0017]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 8th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, The Lighting Sub-Division conditions over said mask including the change process to change said change process, The selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system is included, The zona-orbicularis operation grant process that said 1st setting-out process gives the operation which changes the illumination light in the pupil of said illumination-light study system in the shape of zona orbicularis, The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, Including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, said 2nd setting-out process, The 2nd displacement

process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, and said optic axis, and intersects said 1st direction. An exposure method including the variable power process of making the size of said illumination light variable is provided.
[0018]In the 9th invention of this invention, the illumination-light study system which illuminates an object to be illuminated in the illumination optical device which it had said illumination-light study system, Have a variable means which makes variable either [at least] the size of the illumination light in the pupil of this illumination-light study system, or the form, and said variable means, The illumination optical device having a zona-orbicularis ratio variable means which gives the operation changed in the shape of [with the zona-orbicularis ratio of a request of said illumination light] zona orbicularis, and the 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system is provided.
[0019]According to the desirable mode of the 9th invention, said variable means has a variable power optical system which makes the size of said illumination light variable. As for said variable means, it is preferred to have the 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction. As for said illumination-light study system, it is preferred to have the optical form conversion method which leads the illumination light which changed into the light flux form of the request of the form of said illumination light, and was changed into the light flux form of this request to said variable means. In this case, as for said optical form conversion method, it is preferred to have the 1st diffracted-light study component which changes the form of said illumination light into the 1st light flux form, and the 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes the form of said illumination light into the 2nd light flux form. As for said illumination-light study system, it is preferred to have the optical integrator which is arranged in the optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[0020]In an exposure method which exposes a pattern of a mask to a photosensitive substrate in the 10th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and a projection process of projecting a pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, Either [at least] a size of illumination light in a pupil of said illumination-light study system, or the form including a variable process made variable the aforementioned variable process, zona orbicularis which gives an operation changed in the shape of [with a zona-orbicularis ratio of a request of said illumination light] zona orbicularis -- a ratio -- an exposure method including a variable process and the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system is provided.
[0021]According to the desirable mode of the 10th invention, the aforementioned variable process includes further a variable power process of making a size of said illumination light variable. As for the aforementioned variable process, it is preferred to include further the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction. As for said Lighting Sub-Division process, it is preferred to include further an optical form converting process changed into light flux form of a request of form of said illumination light before the aforementioned variable process. In this case, the 1st diffraction process from which said optical form converting process changes form of said illumination light into the 1st light flux form using the 1st diffracted-light study component, It is preferred to include the 2nd diffraction process of changing form of said illumination light into the 2nd light flux form using said 1st diffracted-light study component and the 2nd diffracted-light study component provided exchangeable. As for said Lighting Sub-Division process, it is preferred to include a uniform illumination process of using an optical integrator and illuminating said object to be illuminated uniformly after the aforementioned variable process.
[0022]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 11th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, The Lighting Sub-Division conditions over said mask including the change process to change said change process, The selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system is included, the zona orbicularis which gives the operation changed in the shape of [in which said 1st setting-out process has a zona-orbicularis ratio of a request of the illumination light in the pupil of said illumination-light study system] zona orbicularis -- a ratio -- with a variable process. The size of said illumination light including the variable power process made variable said 2nd setting-out process, An exposure method including the displacement process which displaces said illumination light symmetrically on both sides of said optic axis along the prescribed direction which intersects perpendicularly with the optic axis of said illumination-light study system, and the variable power process of making the size of said illumination light variable is provided.

[0023]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 12th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process, the zona orbicularis which gives the operation changed in the shape of [with the zona-orbicularis ratio of a request of the illumination light in the pupil of said illumination-light study system] zona orbicularis -- a ratio -- with a variable process. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction is provided.
[0024]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 13th invention of this invention, Including the Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate, said Lighting Sub-Division process,

The Lighting Sub-Division conditions over said mask including the change process to change said change process, The 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system, And at least one of the 3rd setting-out processes of setting up the 3rd Lighting Sub-Division conditions of said illumination-light study system, including the selection process to choose said 1st setting-out process, the zona orbicularis which gives the operation changed in the shape of [with the zona-orbicularis ratio of a request of the illumination light in the pupil of said illumination-light study system] zona orbicularis -- a ratio -- with a variable process. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, Including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, said 2nd setting-out process, the zona orbicularis which gives the operation changed in the shape of [with the zona-orbicularis ratio of a request of said illumination light] zona orbicularis -- a ratio -- said 3rd setting-out process including a variable process and the variable power process of making the size of said illumination light variable. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with the optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and the variable power process of making the size of said illumination light variable is provided.

[0025]In the 14th invention of this invention, the exposure device equipping the 5th invention or the 9th invention for illuminating the mask as said object to be illuminated with the illumination optical device of a description and the projection optical system for projecting the pattern image of said mask on a photosensitive substrate is provided. In the 15th invention of this invention, the manufacturing method of a micro device including the exposure process which exposes the pattern of said mask to said photosensitive substrate using the exposure device of the 14th invention, and the developing process which develops said photosensitive substrate exposed by said exposure process is provided. The exposure process which exposes the pattern of said mask to said photosensitive substrate in the 16th invention of this invention using the exposure method of the 6th invention - the 8th invention or the 10th invention - the 13th invention, The manufacturing method of a micro device including the developing process which develops said photosensitive substrate exposed by said exposure process is provided.

[0026]In the exposure method which exposes the pattern of a mask to a photosensitive substrate in the 17th invention of this invention, The Lighting Sub-Division process of illuminating said mask via an illumination-light study system, and the projection process of projecting the pattern image of said mask on said photosensitive substrate using a projection optical system, The optical property of said projection optical system including the measurement step to measure said Lighting Sub-Division process, The exposing condition setting-out process of setting the sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95 when performing said projection process, An exposure method including the measurement condition setting-out process of setting the sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 when performing said measurement step is provided. In this case, including further the scanning process to which said mask and said photosensitive substrate are moved along a scanning direction when performing said projection process said Lighting Sub-Division process, When setting the length Ls of the transverse direction of said illuminated field, and the length of the longitudinal direction of said illuminated field to Ll including the process of forming the illuminated field of the rectangular shape which has a longitudinal direction and the transverse direction on said mask, it is preferred to fill the relation of 0.05<Ls/Ll<0.7.

[0027]In the exposure device which exposes the pattern of a mask to a photosensitive substrate in the 18th invention of this invention, Have an illumination-light study system which illuminates said mask, and a projection optical system which projects the pattern image of said mask on said photosensitive substrate, and said illumination-light study system, When exposing the pattern of said mask to said photosensitive substrate, set the sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95, and. When [in which the optical property of said projection optical system is measured] measuring, the exposure device having a Lighting Sub-Division conditioning means to set the sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 is provided. In this case, when exposing the pattern of said mask to said photosensitive substrate, It has further a scanning means to which said mask and said photosensitive substrate are moved along a scanning direction, When setting to Ll the length of the longitudinal direction of said illuminated field which sets to Ls the length of the transverse direction of said illuminated field formed in said mask of said illumination-light study system, and is formed in said mask of said illumination-light study system, it is preferred to fill the relation of 0.05<Ls/Ll<0.7.

[0028]

[Mode for carrying out the invention]In the typical embodiment of this invention, the light flux from a light source means is changed into the light flux of the shape of 4 poles, or the shape of zona orbicularis, for example by a light flux sensing element like a diffraction optical element. It is condensed by the predetermined optical system and the light flux of this shape of 4 poles and shape of zona orbicularis enters into a micro fly eye lens or the 1st optical integrator like a microlens array (henceforth a "micro fly eye") from an oblique direction to an optic axis. In this way, the 1st a large number light source is formed of a micro fly eye. The light flux from the 1st a large number light source forms the 2nd a large number light source, i.e., the secondary light source of the shape of 4 poles, or the shape of zona orbicularis, by the 2nd optical integrator like a fly eye lens, after passing a predetermined optical system.

[0029]In this invention, in order to change the degree of incidence angle along a prescribed direction of an incoming beam to a micro fly eye, it has an aspect ratio change element which changes an aspect ratio of an incoming beam. An aspect ratio change element is provided with the following.

For example, the 1st prism that has a refracting interface of a V character-like concave section along a prescribed direction.

The 2nd prism that has a refracting interface of a concave section of the shape of a V character of this 1st prism, and a refracting interface of a convex section of the shape of a V character formed complementarily.

And either is constituted movable in accordance with an optic axis at least among the 1st prism and the 2nd prism.

[0030]Therefore, if an interval of a concave refracting interface of the 1st prism and a convex refracting interface of the shape of a V character of the 2nd prism is changed, a size of the whole secondary light source of the shape of 4 poles or the shape of zona

orbicularis will change along a prescribed direction. As a result, in an illumination optical device of this invention, Lighting Sub-Division conditions which are mutually different for [on an irradiated plane] two way types which intersect perpendicularly are realizable. Therefore, in an exposure device incorporating an illumination optical device of this invention, Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on a mask which has directivity in a pattern can be set up, and a good micro device can be manufactured under good Lighting Sub-Division conditions.

[0031]An embodiment of this invention is described based on an accompanying drawing. Drawing 1 is a figure showing roughly composition of an exposure device provided with an illumination optical device concerning a 1st embodiment of this invention. In drawing 1, the X-axis is set up in the direction vertical to space of drawing 1 along a normal line direction of a wafer which is a photosensitive substrate, respectively in [to a direction parallel to space of drawing 1 / in the Z-axis / / in a wafer surface] a wafer surface for a Y-axis. In drawing 1, it is set up so that an illumination optical device may perform 4 pole Lighting Sub-Division.

[0032]The exposure device of drawing 1 is provided with the excimer laser which supplies light with a wavelength of 248 nm (KrF) or 193 nm (ArF), for example as the light source 1 for supplying exposing light (illumination light). It has the section of rectangular shape which was ejected from the light source 1 along with the Z direction and where the parallel pencil was mostly prolonged long and slender in accordance with the direction of X, and enters into the beam expander 2 which consists of the lens 2a and 2b of a couple. In the space of drawing 1 (inside of a YZ plane), each lens 2a and 2b have negative refracting power and positive refracting power, respectively. Therefore, in the space of drawing 1, the light flux which entered into the beam expander 2 is expanded, and is orthopedically operated by the light flux which has a section of predetermined rectangular shape.

[0033]The almost parallel light flux through the beam expander 2 as a plastic surgery optical system enters into the diffraction optical element (DOE) 4 for 4 pole Lighting Sub-Division, after being deflected in the direction of Y by the bending mirror 3. Generally, a diffraction optical element is constituted by forming the level difference which has a pitch about the wavelength of exposing light (illumination light) in a glass substrate, and has the operation diffracted at the angle of a request of an incident beam. In accordance with four specific directions, it diffracts with equiangularity centering on the optic axis AX, and the light flux which entered into the diffraction optical element 4 for 4 pole Lighting Sub-Division turns into four light flux, i.e., 4 pole-like light flux. Thus, the diffraction optical element 4 constitutes the light flux sensing element for changing the light flux from the light source 1 into 4 pole-like light flux.

[0034]in addition -- a diffraction optical element -- four -- a lighting optical path -- receiving -- insertion and detachment -- free -- constituting -- having -- the zona orbicularis -- Lighting Sub-Division -- ** -- a diffraction optical element -- four -- a -- usually -- circular -- Lighting Sub-Division -- ** -- a diffraction optical element -- four -- b -- a change -- possible -- constituting -- having -- **** . Composition and an operation of the diffraction optical element 4a for zona-orbicularis Lighting Sub-Division and the diffraction optical element 4b usually for circular Lighting Sub-Division are mentioned later. Here, the change between the diffraction optical element 4 for 4 pole Lighting Sub-Division, the diffraction optical element 4a for zona-orbicularis Lighting Sub-Division, and the diffraction optical element 4b usually for circular Lighting Sub-Division is performed by the 1st drive system 22 that operates based on the instructions from the control system 21.

[0035]Light flux of the shape of 4 poles formed via the diffraction optical element 4 enters into the afocal zoom lens (variable power relay optical system) 5, and forms four points (punctiform light source) in a pupil surface. Light from these four points serves as a parallel pencil mostly, is ejected from the afocal zoom lens 5, and enters into the micro fly eye 6. Maintaining the diffraction optical element 4 and an entrance plane of the micro fly eye 6 in an optical almost conjugate relation, and maintaining an afocal system (non-focal optical system), the afocal zoom lens 5 is constituted so that magnification can be continuously changed in the predetermined range. Here, magnification change of the afocal zoom lens 5 is performed by the 2nd drive system 23 that operates based on instructions from the control system 21.

[0036]In this way, light flux enters into an entrance plane of the micro fly eye 6 from an oblique direction almost symmetrically to the optic axis AX. The micro fly eye 6 is an optical element which consists of a microlens which has the positive refractive power of regular hexagon shape of a large number arranged densely and in all directions. Generally, a micro fly eye is constituted by performing an etching process, for example to a plane parallel plate board, and forming a microlens group.

[0037]Here, each microlens which constitutes a micro fly eye is minuter than each lens element which constitutes a fly eye lens. Unlike a fly eye lens which consists of a lens element isolated mutually, a micro fly eye is formed in one, without isolating many microlenses mutually. However, a micro fly eye is the same as a fly eye lens at a point that a lens element which has positive refractive power is arranged in all directions. The number of microlenses which constitute the micro fly eye 6 for clear-izing of Drawings is expressed with drawing 1 very less than the actual condition.

[0038]Therefore, the light flux which entered into the micro fly eye 6 is divided in two dimensions by many microlenses, and an one 4 punctiform light source is formed in the backside focal plane of each microlens, respectively. Thus, the micro fly eye 6 constitutes the 1st optical integrator for forming the 1st a large number light source which consists of many light sources based on the light flux from the light source 1.

[0039]The light flux from the light source of a large number formed in the backside focal plane of the micro fly eye 6 illuminates the fly eye lens 8 as the 2nd optical integrator in superposition via the zoom lens (variable power optical system) 7. The zoom lens 7 is a variable power optical system for sigma value variable to which a focal distance can be continuously changed in the predetermined range, and has connected optically the backside focal plane of the micro fly eye 6, and the backside focal plane of the fly eye lens 8 to conjugate mostly. If it puts in another way, the zoom lens 7 has connected substantially the backside focal plane of the micro fly eye 6, and the entrance plane of the fly eye lens 8 to the relation of the Fourier transform.

[0040]Therefore, every time it attracts the light flux from the 4 punctiform light source of a large number formed in the backside focal plane of the micro fly eye 6 to the backside focal plane of the zoom lens 7, it forms in it the radiation field of the shape of 4 poles which consists of four radiation fields which carried out eccentricity to the entrance plane of the fly eye lens 8 symmetrically to the optic axis AX. The size of the radiation field of the shape of these 4 poles changes depending on the focal distance of the zoom lens 7. Change of the focal distance of the zoom lens 7 is performed by the 3rd drive system 24 that operates based on the instructions from the control system 21.

[0041]The fly eye lens 8 is constituted by arranging the lens element of a large number which have positive refracting power densely and in all directions. Each lens element which constitutes the fly eye lens 8 has a section of rectangular shape [**** / the form (as

a result, form of the exposure region which should be formed on a wafer) of the radiation field which should be formed on a mask]. The field by the side of incidence of each lens element which constitutes the fly eye lens 8 is formed in the sphere form which turned the convex to the incidence side, and the field by the side of an injection is formed in the sphere form which turned the convex to the injection side. Therefore, the light flux which entered into the fly eye lens 8 is divided in two dimensions by many lens elements, and many light sources are formed in the backside focal plane of each lens element into which light flux entered, respectively.
[0042]In this way, as shown in drawing 2, in the backside focal plane of the fly eye lens 8. The secondary light source which has the almost same light intensity distribution as the radiation field formed of the incoming beam to the fly eye lens 8, i.e., the secondary light source of the shape of 4 poles which consists of the four substantial surface light sources 31-34 which carried out eccentricity symmetrically to the optic axis AX, is formed. Thus, the fly eye lens 8 constitutes the 2nd optical integrator for forming the 2nd a large number light source which consists of many light sources more based on the light flux from the 1st a large number light source formed in the backside focal plane of the micro fly eye 6 which is the 1st optical integrator.
[0043]After being restricted via the aperture diaphragm which has a 4 pole-like light transmission section if needed and the light flux from the secondary light source of the shape of 4 poles formed in the backside focal plane of the fly eye lens 8 receives a condensing operation of the condenser optical systems 9, it illuminates in superposition the mask M in which the predetermined pattern was formed. The light flux which penetrated the pattern of the mask M forms the image of a mask pattern via projection optical system PL on the wafer W which is a photosensitive substrate. In this way, the pattern of the mask M is exposed one by one by each exposure region of the wafer W by performing one-shot exposure or scan exposure, carrying out drive controlling of the wafer W in two dimensions into the flat surface (XY plane) which intersects perpendicularly with the optic axis AX of projection optical system PL.
[0044]In one-shot exposure, a mask pattern is exposed in package to each exposure region of a wafer according to what is called a step-and-repeat system. In this case, the form of the illuminated field on the mask M is the rectangular shape near a square, and turns into rectangular shape also with the sectional shape of each lens element of the fly eye lens 8 near a square. On the other hand, in scan exposure, scan exposure of the mask pattern is carried out to each exposure region of a wafer, carrying out relative displacement of a mask and the wafer to a projection optical system according to what is called a step and scanning method. In this case, the ratio of a shorter side and a long side is the rectangular shape of 1:3, and the form of the illuminated field on the mask M turns into rectangular shape [**** / the sectional shape of each lens element of the fly eye lens 8 / this].
[0045]If drawing 2 is referred to again, the secondary light source of the shape of 4 poles formed in the backside focal plane of the fly eye lens 8 comprises the surface light sources 31-34 of four regular hexagon shape. Here, the centers 31a-34a of each surface light source have separated only the same distance from the optic axis AX, and the quadrangle which connects the four centers 31a-34a, and is formed is a square which has a neighborhood parallel to the direction of X, and a Z direction centering on the optic axis AX. That is, the secondary light source of the shape of 4 poles formed with the fly eye lens 8 is in the same physical relationship about the direction of X, and a Z direction.
[0046]Therefore, the sectional shape of the light flux which enters into arbitrary one on the mask M which is an irradiated plane also turns into the shape of 4 poles which has the same physical relationship about the direction of X, and a Z direction. If it puts in another way, Lighting Sub-Division conditions will become the same for [on the mask M / which intersects perpendicularly] two way types (the direction of X, and the direction of Y). So, in a 1st embodiment, in order to realize Lighting Sub-Division conditions which are mutually different for [on the mask M] the two way types which intersect perpendicularly, the V groove axicon 10 which consists of the prism 10a and 10b of a couple into the optical path of the afocal zoom lens 5 is arranged.
[0047]Drawing 3 is a figure showing roughly the composition of the prism of the couple which constitutes the V groove axicon system (only henceforth a "V groove axicon") arranged in the optical path of an afocal zoom lens. As shown in drawing 1 and drawing 3, the V groove axicon 10 comprises the 2nd prism 10b that turned the flat surface to the 1st prism 10a that turned the flat surface to the light source side, and turned the concave refracting interface to the irradiated plane side sequentially from the light source side, and the irradiated plane side, and turned the convex refracting interface to the light source side. The concave refracting interface 10c of the 1st prism 10a comprises two flat surfaces parallel to the direction of X, and has a convex V character-like section along with a Z direction.
[0048]10 d of convex refracting interfaces of the 2nd prism 10b are formed as complementarily as the concave refracting interface 10c of the 1st prism 10a, if it puts in another way so that it can contact as mutually as the concave refracting interface 10c of the 1st prism 10a. That is, 10 d of concave refracting interfaces of the 2nd prism 10b comprise two flat surfaces parallel to the direction of X, and have a V character-like concave section along with a Z direction. At least one side is constituted movable in accordance with the optic axis AX among the 1st prism 10a and the 2nd prism 10b, and the interval of the concave refracting interface 10c and 10 d of convex refracting interfaces is constituted by variable.
[0049]Change of the interval of the V groove axicon 10, i.e., change of the interval of the concave refracting interface 10c and 10 d of convex refracting interfaces, is performed by the 4th drive system 25 that operates based on the instructions from the control system 21. The information about various kinds of masks which should be exposed one by one according to a step-and-repeat system or a step and scanning method, etc. are inputted into the control system 21 via the input means 20 of a keyboard etc.
[0050]Here, in the state where it has contacted mutually, the V groove axicon 10 functions as a plane-parallel plate, and the influence which it has on the secondary light source of the shape of 4 poles formed does not have the concave refracting interface 10c of the 1st prism 10a, and 10 d of convex refracting interfaces of the 2nd prism 10b. However, if the concave refracting interface 10c of the 1st prism 10a and 10 d of convex refracting interfaces of the 2nd prism 10b are made to estrange, the V groove axicon 10 will function as a plane-parallel plate in accordance with the direction of X, but along with a Z direction, it functions as a beam expander.
[0051]Therefore, although the degree of incidence angle which met in the direction of X of the incoming beam to the micro fly eye 6 does not change with change of the interval of the concave refracting interface 10c and 10 d of convex refracting interfaces, the degree of incidence angle which met in the direction of Y of the incoming beam to the micro fly eye 6 changes. As a result, although the centers 31a-34a of each surface light sources 31-34 in drawing 2 do not move in the direction of X, they move to a Z direction. Thus, the V groove axicon 10 constitutes the aspect ratio change element which changes the aspect ratio of an incoming beam in order to change the degree of incidence angle which met in the direction of Y of the incoming beam to the micro fly eye 6.
[0052]Drawing 4 is a figure which illustrates typically the influence which change of the interval of a V groove axicon, change of the magnification of an afocal zoom lens, and change of the focal distance of a zoom lens have on a secondary 4 pole-like light source. As

shown in drawing 4 (a), when the interval of the V groove axicon 10 is zero (i.e., when the concave refracting interface 10c and 10 d of convex refracting interfaces have contacted mutually), each surface light source which constitutes a secondary 4 pole-like light source is formed in the same physical relationship about the direction of X, and a Z direction. And if the interval of the V groove axicon 10 is changed from zero to a predetermined size, as shown in drawing 4 (b), each surface light source moves to a Z direction, without changing the form and size, and although the interval which met in the direction of X of the center of each surface light source does not change, the interval in alignment with a Z direction will be expanded.
[0053]In the state of zero, if the magnification of the afocal zoom lens 5 makes it change, only the same distance as the direction of X and a Z direction will move each surface light source, without changing the form and size, and the interval of the V groove axicon 10 will expand or reduce the interval of each surface light source, as shown in drawing 4 (c). When the interval of the V groove axicon 10 makes [the focal distance of the zoom lens 7] it change, as the state of zero is shown to drawing 4 (d), the secondary whole 4 pole-like light source expands or contracts in similarity. That is, only the distance as the direction of X and a Z direction with each same surface light source moves each surface light source while the size expands or contracts, without changing the form. In order to avoid degradation of the prism components 10a and 10b by laser radiation, it is preferred to separate an interval from the condensing point when four points are formed into the optical path of the afocal zoom lens 5, and to arrange the prism components 10a and 10b.
[0054]by the way -- having mentioned above -- as -- a diffraction optical element -- four -- a lighting optical path -- receiving -- insertion and detachment -- free -- constituting -- having -- and -- the zona orbicularis -- Lighting Sub-Division -- ** -- a diffraction optical element -- four -- a -- usually -- circular -- Lighting Sub-Division -- ** -- a diffraction optical element -- four -- b -- a change -- possible -- constituting -- having -- **** . Zona-orbicularis Lighting Sub-Division obtained by replacing with the diffraction optical element 4 and setting up the diffraction optical element 4a into a lighting optical path hereafter is explained briefly.
[0055]If it replaces with the diffraction optical element 4 for 4 pole Lighting Sub-Division and the diffraction optical element 4a for zona-orbicularis Lighting Sub-Division is set up into a lighting optical path, zona-orbicularis-like light flux will be formed via the diffraction optical element 4a. The light flux of the shape of zona orbicularis formed via the diffraction optical element 4a enters into the afocal zoom lens 5, and forms the image (light source of ring shape) of ring shape in a pupil surface. The light from the image of this ring shape serves as a parallel pencil mostly, is ejected from the afocal zoom lens 5, and forms the 1st a large number light source in the backside focal plane of the micro fly eye 6.
[0056]The light flux from the 1st a large number light source formed of the micro fly eye 6 forms the radiation field of the shape of zona orbicularis centering on the optic axis AX in the entrance plane of the fly eye lens 8 via the zoom lens 7. As a result, the secondary light source which has the almost same light intensity as the radiation field formed in the entrance plane, i.e., the secondary light source of the shape of zona orbicularis centering on the optic axis AX, is formed in the backside focal plane of the fly eye lens 8.
[0057]Drawing 5 is a figure which illustrates typically the influence which change of the interval of a V groove axicon, change of the magnification of an afocal zoom lens, and change of the focal distance of a zoom lens have on a secondary zona-orbicularis-like light source. As shown in drawing 5 (a), when the interval of the V groove axicon 10 is zero (i.e., when the concave refracting interface 10c and 10 d of convex refracting interfaces have contacted mutually), each surface light source which constitutes a secondary zona-orbicularis-like light source is formed in the same physical relationship about the direction of X, and a Z direction. And if the interval of the V groove axicon 10 is changed from zero to a predetermined size, as shown in drawing 5 (b), without changing the width, the size of the secondary whole zona-orbicularis-like light source will expand a secondary zona-orbicularis-like light source to a Z direction, and it will turn into an ellipse annular secondary light source prolonged in the Z direction.
[0058]When the interval of the V groove axicon 10 makes [the magnification of the afocal zoom lens 5] it change, as the state of zero is shown to drawing 5 (c), the outer diameter (size) expands or reduces a secondary zona-orbicularis-like light source, without changing the width. When the interval of the V groove axicon 10 makes [the focal distance of the zoom lens 7] it change, as the state of zero is shown to drawing 5 (d), the secondary whole zona-orbicularis-like light source expands or contracts in similarity. That is, both zona-orbicularis-like the width and the outer diameters of a secondary light source expand or contract.
[0059]Subsequently, usual circular Lighting Sub-Division obtained by replacing with the diffraction optical element 4 or 4a, and setting up the diffraction optical element 4b for circular Lighting Sub-Division into a lighting optical path is explained. The diffraction optical element 4b for circular Lighting Sub-Division has the function to change the light flux of the rectangular shape which entered into the light flux of a circle configuration. Therefore, according to the magnification, it is expanded or reduced by the afocal zoom lens 5, and the light flux of the circle configuration formed of the diffraction optical element 4b enters into the micro fly eye 6.
[0060]In this way, the 1st a large number light source is formed in a backside focal plane of the micro fly eye 6. In an entrance plane of the fly eye lens 8, light flux from the 1st a large number light source formed in a backside focal plane of the micro fly eye 6 forms a radiation field of a circle configuration centering on the optic axis AX via the zoom lens 7. As a result, a secondary light source of a circle configuration centering on the optic axis AX is formed also in a backside focal plane of the fly eye lens 8.
[0061]In this case, if an interval of the V groove axicon 10 is changed from zero to a predetermined size, a secondary light source of a circle configuration will be expanded to a Z direction, and will turn into a secondary light source of the shape of an ellipse prolonged in a Z direction. If magnification of the afocal zoom lens 5 makes it change [interval / of the V groove axicon 10] in a state of zero or a focal distance of the zoom lens 7 makes it change, the whole secondary light source of a circle configuration will expand or contract in similarity. That is, an outer diameter (size) of a secondary light source of a circle configuration expands or contracts.
[0062]As mentioned above, in a 1st embodiment, it changes to a Z direction by changing an interval of the V groove axicon 10, without a size of the whole secondary light source changing in the direction of X. As a result, Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on the mask M which can realize Lighting Sub-Division conditions which are mutually different for two way types with which it intersects perpendicularly on the mask M (the direction of X and the direction of Y), and has directivity in a pattern by extension can be set up.
[0063]As shown in drawing 6 (a), the 1st prism that has a V character-like concave section, and the 2nd prism that has a convex V character-like section constitute the V groove axicon 10 from above-mentioned explanation. However, without being limited to this, as shown in drawing 6 (b), the neighborhood of the peak of a V character-like concave section and a convex section can also be formed in a plane vertical to the optic axis AX. In order for an outside to obtain a comparatively smooth ellipse annular secondary light source or a secondary ellipse-like light source in zona-orbicularis Lighting Sub-Division or circular Lighting Sub-Division, as

shown in drawing 6 (c), it is preferred to form the neighborhood of the peak of a V character-like concave section and a convex section in cylindrical shape.
[0064]It is made to change to a Z direction by changing an interval of the V groove axicon 10 in above-mentioned explanation, without changing a size of the whole secondary light source in the direction of X. However, as shown in drawing 7 (a), the V groove axicon 10 can also be changed in the directions of a request of a size of the whole secondary light source (for example, the direction of X, etc.) by constituting the optic axis AX pivotable as a center.
[0065]As shown in drawing 7 (b), when the operation direction arranges 2 sets of V groove axicons which intersect perpendicularly mutually, a size of the whole secondary light source can also be independently changed to the direction of X, and a Z direction, respectively. In this case, a size of the whole secondary light source can also be independently changed [by constituting the optic axis AX for 2 sets of V groove axicons pivotable as a center in one or independently], respectively for two way types for [arbitrary] two way types which intersect perpendicularly, or arbitrary.
[0066]In a 1st above-mentioned embodiment, it can constitute so that it may be a turret system, for example or the diffraction optical elements 4, 4a, and 4b as a light flux sensing element may be positioned in a lighting optical path using a publicly known slider mechanism.
[0067]In a 1st above-mentioned embodiment, the form of the microlens which constitutes the micro fly eye 6 is set as a right hexagon. This is because it cannot arrange densely but a light volume loss occurs, so the right hexagon is selected as a circularly near polygon in the microlens of a circle configuration. However, the form of each microlens which constitutes the micro fly eye 6 can use other suitable form which includes rectangular shape, for example, without being limited to this.
[0068]In a 1st above-mentioned embodiment, when performing usual circular Lighting Sub-Division, the diffraction optical element 4b is positioned in a lighting optical path, but use of this diffraction optical element 4b is also omissible. In a 1st above-mentioned embodiment, although the diffraction optical element is used as a light flux sensing element, a micro fly eye, a minute prism array, etc. can also be used, for example, without being limited to this. By the way, the detailed explanation about the diffraction optical element which can be used by this invention is indicated by the US,5,850,300,B gazette etc.
[0069]Although it has composition which condenses light from a secondary light source by the condenser optical systems 9, and illuminates the mask M in superposition in a 1st above-mentioned embodiment, The condenser optical systems 9 and a relay optical system which forms an image of a lighting field diaphragm (mask blinds) and this lighting field diaphragm on the mask M between the masks M may be arranged. In this case, the condenser optical systems 9 will condense light from a secondary light source, a lighting field diaphragm will be illuminated in superposition, and a relay optical system will form an image of an opening (light transmission section) of a lighting field diaphragm on the mask M.
[0070]In a 1st above-mentioned embodiment, although two or more element lenses are accumulated and the fly eye lens 8 is formed, it is also possible to make these into a micro fly eye. A micro fly eye provides two or more very small lens sides in a light transmittance state board with techniques, such as etching, at matrix form, as mentioned above. Although there is no difference in a function between a fly eye lens and a micro fly eye substantially about a point which forms two or more light source images, a size of an opening of one element lens (very small lens) can be made very small, It is points, like that a manufacturing cost is substantially reducible and thickness of an optical axis direction can be made very thin, and a micro fly eye is advantageous.
[0071]Drawing 10 is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 2nd embodiment of this invention. Although a 2nd embodiment has composition similar to a 1st embodiment, Replacing with the composition between the bending mirror 3 and the zoom lens 7 and the fly eye lens 8, and the micro fly eye's (microlens array's) 8a being used and the composition between the condenser optical systems 9 and the mask M are fundamentally different from a 1st embodiment. Hereafter, a 2nd embodiment is described paying attention to a point of difference with a 1st embodiment. In drawing 10, it is set up so that an illumination optical device may perform 4 pole Lighting Sub-Division.
[0072]according to a 2nd embodiment, it was ejected from the light source 1 -- a parallel pencil passes the beam expander 2 and the bending mirror 3 mostly -- 4 -- it enters into the diffraction optical element 11a very for Lighting Sub-Division. The diffraction optical element 11a has a function which forms 4 pole-like light intensity distribution in the far field (Fraunhofer diffraction field), when the parallel pencil which has a section of rectangular shape enters. four -- very -- Lighting Sub-Division -- ** -- a diffraction optical element -- 11 -- a -- a lighting optical path -- receiving -- insertion and detachment -- free -- constituting -- having -- the zona orbicularis -- Lighting Sub-Division -- ** -- a diffraction optical element -- 11 -- b -- circular -- Lighting Sub-Division -- ** -- a diffraction optical element -- 11 -- c -- a change -- possible -- constituting -- having -- **** .
[0073]Specifically, the diffraction optical element 11a is supported on the turret board (rotor plate : drawing 10 un-illustrating) pivotable to the circumference of a predetermined axis line parallel to the optic axis AX. The diffraction optical element 11a for two or more 4 pole Lighting Sub-Division from which the characteristic differs, the diffraction optical element 11b for two or more zona-orbicularis Lighting Sub-Division from which the characteristic differs, and the diffraction optical element 11c for two or more circular Lighting Sub-Division from which the characteristic differs are formed in the turret board along with the circumferencial direction. The turret board is constituted pivotable through the central point at the circumference of an axis line parallel to the optic axis AX.
[0074]Therefore, the diffraction optical element of the request chosen from many diffraction optical elements 11a-11c can be positioned in a lighting optical path by rotating a turret board. Rotation (as a result, change between the diffraction optical element 11a, and 11b and 11c) of a turret board is performed by the drive system 26 which operates based on the instructions from the control system 21. However, a well-known sliding method can also perform the change between the diffraction optical element 11a, and 11b and 11c, for example, without being limited to a turret system.
[0075]The light flux through the diffraction optical element 11a as an optical form conversion method enters into the afocal lens (relay optical system) 12. The afocal lens 12 is the afocal system (non-focal optical system) set up so that the position of the predetermined side 13 which the front side focal position and the position of the diffraction optical element 11a are mostly in agreement, and is shown by the rear side focal position and a figure destructive line might be mostly in agreement. Here, the position of the predetermined side 13 is equivalent to the position in which the micro fly eye 6 is installed in a 1st embodiment.
[0076]Therefore, mostly, after [which entered into the diffraction optical element 11a] a parallel pencil forms 4 pole-like light intensity distribution in the pupil surface of the afocal lens 12, it turns into a parallel pencil mostly and is ejected from the afocal lens 12. Although the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16 are arranged sequentially from the light

source side in the optical path between the front side lens group 12a of the afocal lens 12, and the back side lens group 12b, the detailed composition and operation are mentioned later. Hereafter, in order to simplify explanation, an operation of these axicons 14-16 is disregarded, and the fundamental composition and operation of a 2nd embodiment are explained.

[0077]The light flux through the afocal lens 12 enters into the micro fly eye 8a as an optical integrator via the zoom lens 7 for sigma value variable (variable power optical system). With a sigma value, the size (diameter) of the pupil of projection optical system PL is set to R1, The size (diameter) of the illumination luminous flux formed in the pupil of projection optical system PL or a light source image is set to R2, The numerical aperture by the side of the mask (reticle) M of projection optical system PL is set to NAo, and when setting to NAi the numerical aperture of an illumination-light study system which illuminates the mask (reticle) M, it defines as sigma=NAi/NAo=R2/R1. However, in zona-orbicularis Lighting Sub-Division, R2 is an outer diameter of zona-orbicularis-like illumination luminous flux or a zona-orbicularis-like light source image formed in the pupil of projection optical system PL, and NAi is a numerical aperture defined with the outer diameter of the zona-orbicularis light flux formed in the pupil of an illumination-light study system. In multi-electrode Lighting Sub-Division, such as 4 pole Lighting Sub-Division, R2 is the size or diameter of a circle circumscribed to the multipolar illumination luminous flux or the multipolar light source image formed in the pupil of projection optical system PL, NAi is a numerical aperture defined with the size or diameter of a circle circumscribed to the multipolar illumination luminous flux formed in the pupil of an illumination-light study system. When in zona-orbicularis Lighting Sub-Division considering the outer diameter of zona-orbicularis-like illumination luminous flux as a zona-orbicularis ratio and setting the inside diameter of the illumination luminous flux of Ro and the shape of zona orbicularis to Ri, it defines as Ri/Ro.

[0078]The position of the predetermined side 13 is arranged near the front side focal position of the zoom lens 7, and the entrance plane of the micro fly eye 8a is arranged near the rear side focal position of the zoom lens 7. If it puts in another way, the zoom lens 7 will have arranged substantially the predetermined side 13 and the entrance plane of the micro fly eye 8a in the relation of the Fourier transform, and will arrange optically the pupil surface of the afocal lens 12, and the entrance plane of the micro fly eye 8a to conjugate mostly by extension. Therefore, on the entrance plane of the micro fly eye 8a which has the same function as the fly eye lens 8 in a 1st embodiment, the radiation field of the shape of 4 poles which consists of four radiation fields which carried out eccentricity, for example to the optic axis AX like the pupil surface of the afocal lens 12 is formed. Here, although it depends on the characteristic of the diffraction optical element 11a for the form of each radiation field which constitutes a 4 pole-like radiation field, the radiation field of the shape of 4 poles which consists of a radiation field of four circle configurations here shall be formed. The whole shape of the radiation field of the shape of these 4 poles changes in similarity depending on the focal distance of the zoom lens 7.

[0079]Each microlens which constitutes the micro fly eye 8a has a section of rectangular shape [**** / the form (as a result, form of the exposure region which should be formed on the wafer W) of the radiation field which should be formed on the mask M]. The light flux which entered into the micro fly eye 8a is divided in two dimensions by many microlenses, The secondary light source which has the almost same light intensity distribution as the radiation field formed of the incoming beam to the micro fly eye 8a, i.e., the secondary light source of the shape of 4 poles which consists of the substantial surface light source of four circle configurations which carried out eccentricity to the optic axis AX, is formed in an after that side focal plane (as a result, pupil of an illumination-light study system).

[0080]Light flux from a secondary light source of the shape of 4 poles formed in a backside focal plane of the micro fly eye 8a illuminates the mask blinds 17 as a lighting field diaphragm in superposition, after receiving a condensing operation of the condenser optical systems 9. Light flux through an opening (light transmission section) of rectangular shape of the mask blinds 17 illuminates the mask M in superposition, after receiving a condensing operation of the image formation optical system 18. Light flux which penetrated a pattern of the mask M forms an image of a mask pattern on the wafer W via projection optical system PL. A variable aperture diaphragm for specifying a numerical aperture of projection optical system PL is provided in an entrance pupil side of projection optical system PL, and a drive of this variable aperture diaphragm is performed by the drive system 27 which operates based on instructions from the control system 21.

[0081]Drawing 11 is a perspective view showing roughly composition of three axicon systems (only henceforth an "axicon") arranged in a 2nd embodiment in an optical path between a front side lens group of an afocal lens, and a back side lens group. According to a 2nd embodiment, as shown in drawing 11, the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16 are arranged sequentially from the light source side in an optical path between the front side lens group 12a of the afocal lens 12, and the back side lens group 12b.

[0082]The cone axicon 14 comprises the 2nd prism component 14b which turned the flat surface to the 1st prism component 14a which turned the flat surface to the light source side, and turned the concave cone-like refracting interface to the mask side sequentially from the light source side, and the mask side, and turned the refracting interface of convex conical shape to the light source side. And the refracting interface of the shape of a concave cone of the 1st prism component 14a and the refracting interface of the convex conical shape of the 2nd prism component 14b are complementarily formed so that it can contact mutually.

[0083]At least one component is constituted movable in accordance with the optic axis AX among the 1st prism component 14a and the 2nd prism component 14b, and the interval of the refracting interface of the shape of a concave cone of the 1st prism component 14a and the refracting interface of the convex conical shape of the 2nd prism component 14b is constituted by variable. Change of the interval of the cone axicon 14 is performed by the drive system 28a which operates based on the instructions from the control system 21.

[0084]Here, in the state where the concave cone-like refracting interface of the 1st prism component 14a and the convex conical shape refracting interface of the 2nd prism component 14b have contacted mutually, the cone axicon 14 functions as a plane-parallel plate, and there is no influence which it has on the secondary light source of the shape of 4 poles formed. However, if the concave cone-like refracting interface of the 1st prism component 14a and the convex conical shape refracting interface of the 2nd prism component 14b are made to estrange, the cone axicon 14 will function as what is called a beam expander. Therefore, the angle of the incoming beam to the predetermined side 13 changes with change of the interval of the cone axicon 14.

[0085]The 1st V groove axicon 15 comprises the 2nd prism component 15b which turned the flat surface to the light source side, and turned the flat surface to the 1st prism component 15a which is a concave and turned the V character-like refracting interface to the mask side, and the mask side, and is convex and turned the V character-like refracting interface to the light source side. The

concave refracting interface of the 1st prism component 15a comprised two flat surfaces, and the nodal line is prolonged along with the Z direction. The convex refracting interface of the 2nd prism component 15b is formed as complementarily as the concave refracting interface of the 1st prism component 15a, if it puts in another way so that it can contact as mutually as the concave refracting interface of the 1st prism component 15a.

[0086]That is, the convex refracting interface of the 2nd prism component 15b also comprised two flat surfaces, and the nodal line is prolonged along with the Z direction. At least one side is constituted movable in accordance with the optic axis AX among the 1st prism component 15a and the 2nd prism component 15b, and the interval of the concave refracting interface of the 1st prism component 15a and the convex refracting interface of the 2nd prism component 15b is constituted by variable. Change of the interval of the 1st V groove axicon 15 is performed by the drive system 28b which operates based on the instructions from the control system 21.

[0087]The 2nd V groove axicon 16 comprises the 2nd prism component 16b which turned the flat surface to the 1st prism component 16a which turned the flat surface to the light source side, and turned the V character-like refracting interface to the mask side by the concave, and the mask side, and is convex and turned the V character-like refracting interface to the light source side. The concave refracting interface of the 1st prism component 16a comprised two flat surfaces, and the nodal line is prolonged in accordance with the direction of X. The convex refracting interface of the 2nd prism component 16b is formed as complementarily as the concave refracting interface of the 1st prism component 16a. That is, the convex refracting interface of the 2nd prism component 16b also comprised two flat surfaces, and the nodal line is prolonged in accordance with the direction of X.

[0088]At least one side is constituted movable in accordance with the optic axis AX among the 1st prism component 16a and the 2nd prism component 16b, and the interval of the concave refracting interface of the 1st prism component 16a and the convex refracting interface of the 2nd prism component 16b is constituted by variable. Change of the interval of the 2nd V groove axicon 16 is performed by the drive system 28c which operates based on the instructions from the control system 21.

[0089]Here, in the state where the concave refracting interface and convex refracting interface which counter have contacted mutually, the 1st V groove axicon 15 and the 2nd V groove axicon 16 function as plane-parallel plates, and there is no influence which it has on the secondary light source of the shape of 4 poles formed. However, if the 1st V groove axicon 15 makes a concave refracting interface and a convex refracting interface estrange, it will function as a plane-parallel plate along with a Z direction, but it functions as a beam expander in accordance with the direction of X. If the 2nd V groove axicon 16 makes a concave refracting interface and a convex refracting interface estrange, it will function as a plane-parallel plate in accordance with the direction of X, but it functions as a beam expander along with a Z direction.

[0090]Drawing 12 is a figure explaining an operation of the cone axicon to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment. In 4 pole Lighting Sub-Division of a 2nd embodiment, by making the interval of the cone axicon 14 expand from zero to a predetermined value, While each surface light sources 40a-40d of the circle configuration which constitutes a secondary 4 pole-like light source move to the method of outside along the radial direction of the circle centering on the optic axis AX, the form changes from a circle configuration to elliptical. That is, the line segment which connects the surface light sources [each / 40a-40d] of the circle configuration before change central point and the each elliptical [after change] surface light sources [41a-41d] central point passes along the optic axis AX, and it depends for the migration length of the central point on the interval of the cone axicon 14.

[0091]An angle (angle which a tangent of a couple from the optic axis AX to each surface light sources 40a-40 makes) which expects each surface light sources 40a-40d of a circle configuration before change from the optic axis AX, and an angle which expects each surface light sources 41a-41d elliptical [after change] from the optic axis AX are equal. And a minor axis along a radial direction of a circle centering on the each an each surface light sources [of a circle configuration before change / 40a-40d] diameter and elliptical [after change] surface light sources [41a-41d] optic axis AX is equal. It depends for a size of a major axis along a hoop direction of a circle centering on the each elliptical [after change] surface light sources [41a-41d] optic axis AX on an each surface light sources [of a circle configuration before change / 40a-40d] diameter, and an interval of the cone axicon 14.

[0092]Therefore, if an interval of the cone axicon 14 is made to expand from zero to a predetermined value, The outer diameter and a zona-orbicularis ratio can be changed without a secondary light source of the shape of 4 poles which comprises the surface light source of four circle configurations changing to a secondary light source of the shape of 4 poles which comprises the four elliptical surface light source, and changing width of a secondary light source before change. Here, width of a secondary 4 pole-like light source is specified as 1/2 of a difference of a diameter of circle, a diameter of circle, i.e., an outer diameter, which are circumscribed to the four surface light sources, i.e., an inside diameter, inscribed in the four surface light sources. A zona-orbicularis ratio of a secondary 4 pole-like light source is specified as a ratio (an inside diameter/outer diameter) of an inside diameter to an outer diameter.

[0093]Drawing 13 is a figure explaining an operation of the zoom lens to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment. In 4 pole Lighting Sub-Division of a 2nd embodiment, change of the focal distance of the zoom lens 7 will change in similarity the whole shape of the secondary light source of the shape of 4 poles which comprises the surface light sources 42a-42d of four circle configurations. That is, each surface light sources 42a-42d of the circle configuration which constitutes a secondary 4 pole-like light source move along the radial direction of the circle centering on the optic axis AX, with a circle configuration maintained.

[0094]And the line segment which connects the surface light sources [before change / each / 42a-42d] central point and the each surface light sources [after change / 43a-43d] central point passes along the optic axis AX, and the migration length of the central point and the direction to movement are dependent on change of the focal distance of the zoom lens 7. The angle which expects each surface light sources 42a-42d before change from the optic axis AX, and the angle which expects each surface light sources 43a-43d after change from the optic axis AX are equal. In this way, only the outer diameter can be changed by changing the focal distance of the zoom lens 7, without changing the zona-orbicularis ratio of a secondary 4 pole-like light source.

[0095]Drawing 14 is a figure explaining an operation of the 1st V groove axicon to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon. Although the degree of incidence angle in alignment with the Z direction of the incoming beam to the predetermined side 13 does not change with change of the interval of the 1st V groove axicon 15, the degree of incidence angle which met in the direction of X of the incoming beam to the predetermined side 13 changes. As a

result, as shown in drawing 14 (a), although the surface light sources 44a-44d of four circle configurations do not move to a Z direction, they move in the direction of X, with the form and size maintained. Namely, if the interval of the 1st V groove axicon 15 is expanded from zero to a predetermined value, the surface light sources 44b and 44c will move in the direction of -X, and will move the surface light sources 44a and 44d in the direction of +X.

[0096]On the other hand, although the degree of incidence angle which met in the direction of X of the incoming beam to the predetermined side 13 does not change with change of the interval of the 2nd V groove axicon 16, the degree of incidence angle in alignment with the Z direction of the incoming beam to the predetermined side 13 changes. As a result, as shown in drawing 14 (b), although the surface light sources 44a-44d of four circle configurations do not move in the direction of X, they move to a Z direction, with the form and size maintained. That is, if the interval of the 2nd V groove axicon 16 is expanded from zero to a predetermined value, the surface light sources 44a and 44b will move to + Z direction, and will move the surface light sources 44c and 44d to - Z direction.

[0097]Change of both the interval of the 1st V groove axicon 15 and the interval of the 2nd V groove axicon 16 will change both the degrees of incidence angle in alignment with the degree of incidence angle and Z direction which met in the direction of X of the incoming beam to the predetermined side 13. As a result, as shown in drawing 14 (c), each surface light sources 44a-44d move in a Z direction and the direction of X, with the form and size maintained. Namely, if the interval of the 1st V groove axicon 15 and the interval of the 2nd V groove axicon 16 are expanded to a value predetermined [both] from zero, The surface light source 44a moves in + Z direction and the direction of +X, the surface light source 44b moves in + Z direction and the direction of -X, the surface light source 44c moves in - Z direction and the direction of -X, and 44 d of surface light sources move it in - Z direction and the direction of +X.

[0098]As mentioned above, the cone axicon 14 constitutes the zona-orbicularis ratio variable means which makes variable the zona-orbicularis ratio of the illumination light in the pupil (backside focal plane of the micro fly eye 8a) of an illumination-light study system. The zoom lens 7 constitutes the variable power optical system which makes variable the size of the illumination light in the pupil of an illumination-light study system. The 1st V groove axicon 15 constitutes the 1st displacement means that displaces the illumination light symmetrically on both sides of the optic axis AX in accordance with the direction of X in the pupil of an illumination-light study system. The 2nd V groove axicon 16 constitutes the 2nd displacement means that displaces the illumination light symmetrically on both sides of the optic axis AX along with a Z direction in the pupil of an illumination-light study system. And the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7 constitute the variable means which makes variable the size and form of the illumination light in the pupil of an illumination-light study system.

[0099]Drawing 15 is a figure explaining an operation of the cone axicon to each surface light source of the circle configuration formed in 4 pole Lighting Sub-Division of a 2nd embodiment, a zoom lens, the 1st V groove axicon, and the 2nd V groove axicon. In both drawing 15, the interval of the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16 by zero And the state where the focal distance of the zoom lens 7 was set as the minimum. Its attention is paid to the one surface light source 45a in the surface light source of four circle configurations which constitute the secondary light source of the shape of smallest 4 poles formed by (it is hereafter called a "normal condition").

[0100]If an interval of the 1st V groove axicon 15 is made to expand from zero to a predetermined value by this normal condition, the surface light source 45a will move in accordance with the direction of X, with that form and size maintained, and will reach a position shown by the reference agreement 45b. Subsequently, if an interval of the 2nd V groove axicon 16 is made to expand from zero to a predetermined value, the surface light source 45b will move along with a Z direction, with the form and size maintained, and will reach a position shown by the reference agreement 45c.

[0101]If a focal distance of the zoom lens 7 is made to expand from the minimum to a predetermined value, the surface light source 45c of a circle configuration will move to a method of outside along a radial direction of a circle centering on the optic axis AX while expanding it, with the circle configuration maintained, and will reach a position shown by 45 d of reference agreements. If an interval of the cone axicon 14 is made to expand from zero to a predetermined value if needed, 45 d of surface light sources of a circle configuration will move to a method of outside along a radial direction of a circle centering on the optic axis AX while changing to elliptical [which was expanded from a circle configuration], and will reach a position shown by the reference agreement 45e.

[0102]Even if it makes an interval of the 1st V groove axicon 15 expand from zero to a predetermined value after making an interval of the 2nd V groove axicon 16 expand from zero to a predetermined value, the surface light source 45a reaches a position shown by the reference agreement 45c with the form and size maintained. Similarly, depending on change of an interval of the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16, and change of a focal distance of the zoom lens 7, it does not depend for a position, form, and a size of the surface light source acquired eventually in order of the change.

[0103]By in this way, operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7. It can continue broadly, and the position of each surface light source which constitutes a secondary 4 pole-like light source can be moved, and the form and size can be changed [the predetermined range]. However, actually, the rate of a flow rate of each surface light source by the cone axicon 14, the 1st V groove axicon 15, or the 2nd V groove axicon 16 (namely, coordinates position of the surface light source of the move origin to the coordinates position of the surface light source of a movement destination) has the restrictions on an optical design, and the moving range of each surface light source has restriction.

[0104]So, in a 2nd embodiment, it has three kinds of diffraction optical elements from which the characteristic differs as the diffraction optical element 11a for 4 pole Lighting Sub-Division. Drawing 16 is a figure explaining each surface light source formed via three kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in a 2nd embodiment, and its moving range. Its attention is paid to the one surface light source 46 in the surface light source of four circle configurations which constitute the secondary light source of the shape of smallest 4 poles formed by a normal condition like drawing 15 also in drawing 16.

[0105]According to a 2nd embodiment, a secondary 4 pole-like light source in which the quadrangle which connects the central point of the four surface light sources, and is formed of the 1st diffraction optical element for 4 pole Lighting Sub-Division turns into a long and slender rectangle in accordance with the direction of X, i.e., the secondary light source of the shape of 4 poles as shown in the right-hand side of drawing 14 (a), is formed. The one surface light source 46a in the surface light source of four circle configurations which constitute the secondary light source of the shape of 4 poles formed via the 1st diffraction optical element for 4 pole Lighting

Sub-Division moves within the limits of the rectangular shape shown with the reference mark 47a by operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16.
[0106]A secondary 4 pole-like light source in which the quadrangle which connects the central point of the four surface light sources, and is formed of the 2nd diffraction optical element for 4 pole Lighting Sub-Division, on the other hand, turns into a long and slender rectangle along with a Z direction, i.e., the secondary light source of the shape of 4 poles as shown in the right-hand side of drawing 14 (b), is formed. The one surface light source 46b in the surface light source of four circle configurations which constitute the secondary light source of the shape of 4 poles formed via the 2nd diffraction optical element for 4 pole Lighting Sub-Division moves within the limits of the rectangular shape shown with the reference mark 47b by operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16.
[0107]A secondary 4 pole-like light source in which the quadrangle which connects the central point of the four surface light sources, and is formed of the 3rd diffraction optical element for 4 pole Lighting Sub-Division turns into a square, i.e., the secondary light source of the shape of 4 poles as shown in the right-hand side (or left-hand side of drawing 14 (a) - (c)) of drawing 14 (c), is formed. The one surface light source 46c in the surface light source of four circle configurations which constitute the secondary light source of the shape of 4 poles formed via the 3rd diffraction optical element for 4 pole Lighting Sub-Division moves within the limits of the rectangular shape shown with the reference mark 47c by operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16.
[0108]In this way, even if it is a case where the rate of a flow rate of each surface light source by the 1st V groove axicon 15 or the 2nd V groove axicon 16 (as a result, the moving range) is restricted to some extent from a viewpoint of an optical design, in a 2nd embodiment, By using together three kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs, the position of each surface light source can be moved free in the circular field centering on the optic axis AX. Although the graphic display was omitted in drawing 16, in the circular field centering on the optic axis AX, the position, the form, and the size of each surface light source can also be suitably changed into a desired state by operation of the cone axicon 14 and the zoom lens 7.
[0109]In the 1st modification of a 2nd embodiment, it has four kinds of diffraction optical elements from which the characteristic differs as the diffraction optical element 11a for 4 pole Lighting Sub-Division. Drawing 17 and drawing 18 are the figures explaining each surface light source formed via four kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in the 1st modification of a 2nd embodiment, its movement, and modification. Its attention is paid to the one surface light source 48 in the surface light source of four circle configurations which constitute the secondary light source of the shape of smallest 4 poles formed by a normal condition like drawing 15 and drawing 16 also in drawing 17 and drawing 18.
[0110]In the 1st modification of a 2nd embodiment, as shown in drawing 17 and drawing 18, The 4 semicircle field specified by the circle centering on the optic axis AX, the line segment parallel to the X-axis, and a line segment parallel to the Z-axis is divided into four sectorial regions by three line segments which pass along the optic axis AX, It is set up so that an each surface light sources [of the circle configuration formed, respectively of four kinds of diffraction optical elements for 4 pole Lighting Sub-Division / 48a-48d] center may be located in each sectorial region. That is, it is set up so that the surface light source 48a may be formed of the 1st diffraction optical element, the surface light source 48b may be formed of the 2nd diffraction optical element, the surface light source 48c may be formed of the 3rd diffraction optical element and 48 d of surface light sources may be formed of the 4th diffraction optical element.
[0111]Hereafter, since explanation is easy, the division-into-equal-parts rate of the 4 semicircle field shall be carried out to four sectorial regions, and it shall be arranged along the hoop direction of the circle centering on the optic axis AX so that each surface light sources 48a-48d may touch mutually. In this case, if the interval of the cone axicon 14 is made to expand from zero to a predetermined value, as shown in drawing 17, While each surface light sources 48a-48d change to elliptical [which the form expanded from the circle configuration], the center position moves to the method of outside along the radial direction of the circle centering on the optic axis AX, and reaches the position shown by the reference agreements 49a-49d, respectively.
[0112]While expanding each surface light sources 48a-48d, with the circle configuration maintained as shown in drawing 18 if the focal distance of the zoom lens 7 is made to expand from the minimum to a predetermined value, The center position moves to the method of outside along the radial direction of the circle centering on the optic axis AX, and reaches the position shown by the reference agreements 50a-50d, respectively. In this way, in the 1st modification of a 2nd embodiment, the position, the form, and the size of each surface light source can be changed free in the circular field centering on the optic axis AX by using together four kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs.
[0113]In drawing 17 and drawing 18, it arranges so that each surface light sources 48a-48d may touch mutually, but it can also arrange so that each surface light sources 48a-48d may separate an interval mutually. In any case, in the circular field centering on the optic axis AX, it can change into the state of a request of the position, the form, and the size of each surface light source suitably by operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7.
[0114]In the 2nd modification of a 2nd embodiment, it has two kinds of diffraction optical elements from which the characteristic differs as the diffraction optical element 11a for 4 pole Lighting Sub-Division. Drawing 19 is a figure explaining each surface light source formed via two kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in the 2nd modification of a 2nd embodiment, its movement, and modification. Its attention is paid to the one surface light source 51 in the surface light source of four circle configurations which constitute the secondary light source of the shape of smallest 4 poles formed by a normal condition like drawing 15 - drawing 18 also in drawing 19.
[0115]In the 2nd modification of a 2nd embodiment, a secondary 4 pole-like light source in which the quadrangle which connects the central point of the four surface light sources, and is formed of one diffraction optical element for 4 pole Lighting Sub-Division turns into a long and slender rectangle in accordance with the direction of X is formed. The one surface light source 51a (it corresponds to 46a of drawing 16) in the surface light source of four circle configurations which constitute the secondary light source of the shape of 4 poles formed via one diffraction optical element for 4 pole Lighting Sub-Division, By operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16, it moves within the limits of the rectangular shape shown with the reference mark 52a.
[0116]A secondary 4 pole-like light source in which the quadrangle which connects the central point of the four surface light sources, and is formed of the diffraction optical element for 4 pole Lighting Sub-Division of another side turns into a long and slender rectangle along with a Z direction is formed. The one surface light source 51b (it corresponds to 46b of drawing 16) in the surface light source

of four circle configurations which constitute the secondary light source of the shape of 4 poles formed via the diffraction optical element for 4 pole Lighting Sub-Division of another side. By operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16, it moves within the limits of the rectangular shape shown with the reference mark 52b.

[0117]one 4 -- very -- 4 of the concomitant use with the diffraction optical element for Lighting Sub-Division, and the 2nd V groove axicon 16, or another side — the surface light source 51c is formed very much in an interim position with the first stage surface light sources 51a and 51b by concomitant use with the diffraction optical element for Lighting Sub-Division, and the 1st V groove axicon 15. In this case, while expanding the surface light source 51c by making the variable power function of the zoom lens 7 act to the surface light source 51c, with that circle configuration maintained, that center position moves to the method of outside along the radial direction of the circle centering on the optic axis AX, and reaches the position shown by 51 d of reference agreements.

[0118]Or although the graphic display was omitted, while the surface light source 51c changes to elliptical [which the circle configuration expanded] by making the cone axicon 14 act to the surface light source 51c, the center position moves to the method of outside along the radial direction of the circle centering on the optic axis AX. In this way, in the 2nd modification of a 2nd embodiment, the position of each surface light source can be moved free in the circular field centering on the optic axis AX by using together two kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs. Generally the position, the form, and the size of each surface light source can be suitably changed into a desired state in the circular field centering on the optic axis AX by operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7.

[0119]Next, zona-orbicularis Lighting Sub-Division obtained by replacing with the diffraction optical element 11a for 4 pole Lighting Sub-Division, and setting up the diffraction optical element 11b for zona-orbicularis Lighting Sub-Division into a lighting optical path is explained briefly. In this case, mostly, after [which entered into the diffraction optical element 11b] a parallel pencil forms zona-orbicularis-like light intensity distribution in the pupil surface of the afocal lens 12, it turns into a parallel pencil mostly and is ejected from the afocal lens 12. The light flux through the afocal lens 12 forms the radiation field of the shape of zona orbicularis centering on the optic axis AX in the entrance plane of the micro fly eye 8a via the zoom lens 7. As a result, the secondary light source which has the almost same light intensity distribution as the radiation field formed of the incoming beam, i.e., the secondary light source of the shape of zona orbicularis centering on the optic axis AX, is formed in the backside focal plane of the micro fly eye 8a.

[0120]Drawing 20 is a figure explaining an operation of the cone axicon to the secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment. In zona-orbicularis Lighting Sub-Division of a 2nd embodiment, the secondary smallest zona-orbicularis-like light source 60a formed by the normal condition by making the interval of the cone axicon 14 expand from zero to a predetermined value, It changes to the secondary light source 60b of the shape of zona orbicularis to which the outer diameter and inside diameter were expanded [both], without the width (1/2 of the difference of an outer diameter and an inside diameter: a figure Nakaya seal shows) changing. If it puts in another way, as for a secondary zona-orbicularis-like light source, the zona-orbicularis ratio and size (outer diameter) will change [both] with operations of the cone axicon 14, without the width changing.

[0121]Drawing 21 is a figure explaining an operation of a zoom lens to a secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment. In zona-orbicularis Lighting Sub-Division of a 2nd embodiment, the secondary light source 60a of the shape of zona orbicularis formed by a normal condition changes to the secondary light source 60c of the shape of zona orbicularis to which the whole shape was expanded in similarity by making a focal distance of the zoom lens 7 expand from the minimum to a predetermined value. If it puts in another way, as for a secondary zona-orbicularis-like light source, the width and size (outer diameter) will change [both] with operations of the zoom lens 7, without the zona-orbicularis ratio changing.

[0122]Drawing 22 is a figure explaining an operation of the 1st V groove axicon to a secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon. As mentioned above, the degree of incidence angle in alignment with a Z direction of an incoming beam to the predetermined side 13 does not change with change of an interval of the 1st V groove axicon 15, but the degree of incidence angle which met in the direction of X of an incoming beam to the predetermined side 13 changes. As a result, as shown in drawing 22 (a), although each surface light sources 61-64 of four 4 semicircular arcs which constitute the secondary zona-orbicularis-like light source 60a do not move to a Z direction, they move in the direction of X. Namely, if an interval of the 1st V groove axicon 15 is expanded to a predetermined value from zero, the surface light sources 61 and 63 will move in the direction of -X, and will move the surface light sources 62 and 64 in the direction of +X.

[0123]On the other hand, although the degree of incidence angle which met in the direction of X of the incoming beam to the predetermined side 13 does not change with change of the interval of the 2nd V groove axicon 16, the degree of incidence angle in alignment with the Z direction of the incoming beam to the predetermined side 13 changes. As a result, as shown in drawing 22 (b), although each surface light sources 61-64 do not move in the direction of X, they move to a Z direction. That is, if the interval of the 2nd V groove axicon 16 is expanded to a predetermined value from zero, the surface light sources 61 and 62 will move to + Z direction, and will move the surface light sources 63 and 64 to - Z direction.

[0124]Change of both the interval of the 1st V groove axicon 15 and the interval of the 2nd V groove axicon 16 will change both the degrees of incidence angle in alignment with the degree of incidence angle and Z direction which met in the direction of X of the incoming beam to the predetermined side 13. As a result, as shown in drawing 22 (c), each surface light sources 61-64 move in a Z direction and the direction of X. Namely, if the interval of the 1st V groove axicon 15 and the interval of the 2nd V groove axicon 16 are expanded to a predetermined value from zero, The surface light source 61 moves in + Z direction and the direction of -X, the surface light source 62 moves in + Z direction and the direction of +X, the surface light source 63 moves in - Z direction and the direction of -X, and the surface light source 64 moves it in - Z direction and the direction of +X. In this way, the secondary light source of the shape of 4 poles which consists of the four independent circular surface light sources can be formed.

[0125]As mentioned above, although an operation of the cone axicon 14 in zona-orbicularis Lighting Sub-Division of a 2nd embodiment, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7 was explained individually, zona-orbicularis Lighting Sub-Division of various forms is possible by an interaction of these optical members. In the state which shows in drawing 22 (c), if the zoom lens 7 is made to act, the surface light source 62 will move along a radial direction of a circle centering on the optic axis AX, and, specifically, the whole shape will change to the surface light source 62a which changed in similarity, for example. On the other hand, in the state which shows in drawing 22 (c), if the cone axicon 14 is made to act, the surface light source 64 moves along a radial direction of a circle centering on the optic axis AX, and a size of the radial direction will change to the surface light source

64a from which only a size of the hoop direction changed, for example, without changing.
[0126]However, the change range of a zona-orbicularis ratio by the cone axicon 14 has restriction by the restrictions on an optical design actually. So, in a 2nd embodiment, it has two kinds of diffraction optical elements from which the characteristic differs as the diffraction optical element 11b for zona-orbicularis Lighting Sub-Division. That is, in a 2nd embodiment, a secondary light source of the shape of zona orbicularis which has the form where it was suitable for changing a zona-orbicularis ratio, for example in 0.5-0.68 by one diffraction optical element for zona-orbicularis Lighting Sub-Division is formed. A secondary light source of the shape of zona orbicularis which has the form where it was suitable for changing a zona-orbicularis ratio, for example in 0.68-0.8 by a diffraction optical element for zona-orbicularis Lighting Sub-Division of another side is formed. As a result, concomitant use of two kinds of diffraction optical elements for zona-orbicularis Lighting Sub-Division enables it to change a zona-orbicularis ratio in 0.5-0.8.
[0127]By the way, when drawing 23 (a) is referred to, it turns out that curvature of a circle (a figure destructive line shows) and curvature of an outside circle of the surface light source of a half a yen each arc which are circumscribed to a secondary light source of the shape of 2 poles acquired on the right-hand side of drawing 22 (a) or (b) are not in agreement. So, in the 3rd modification of a 2nd embodiment, in order to coincide curvature of a circle circumscribed to a secondary light source of the shape of 2 poles acquired by operation of the 1st V groove axicon 15 or the 2nd V groove axicon 16, and curvature of an outside circle of each semicircular arc surface light source, the 3rd diffraction optical element for zona-orbicularis Lighting Sub-Division is attached. The 3rd diffraction optical element for zona-orbicularis Lighting Sub-Division forms a slightly flat ellipse annular secondary light source along with not a secondary light source but the direction of X or a Z direction of the shape of perfect zona orbicularis which is specified by two circles centering on the optic axis AX, as shown in drawing 23 (b).
[0128]More particularly, the ellipse annular secondary light source formed of the 3rd diffraction optical element for zona-orbicularis Lighting Sub-Division comprises the circular surface light sources 65a and 65b of a couple. The curvature of the outside circle of each surface light sources 65a and 65b is set up it be in agreement with the curvature of the circle circumscribed to the secondary light source of the shape of 2 poles acquired by operation of the 1st V groove axicon 15 or the 2nd V groove axicon 16. Therefore, in the 3rd modification of a 2nd embodiment. In the secondary light source of the shape of 2 poles acquired by operation of the 1st V groove axicon 15 or the 2nd V groove axicon 16, the curvature of the circle circumscribed to the secondary light source of the shape of these 2 poles and the curvature of the outside circle of each circular surface light sources 65a and 65b of surface light source each are in agreement.
[0129]Usual circular Lighting Sub-Division obtained by replacing with the diffraction optical element 11a for 4 pole Lighting Sub-Division or the diffraction optical element 11b for zona-orbicularis Lighting Sub-Division, and setting up the diffraction optical element 11c for circular Lighting Sub-Division into a lighting optical path is explained briefly. In this case, mostly, after [which entered into the diffraction optical element 11c] a parallel pencil forms the light intensity distribution of a circle configuration in the pupil surface of the afocal lens 12, it turns into a parallel pencil mostly and is ejected from the afocal lens 12.
[0130]The light flux through the afocal lens 12 forms the radiation field of the circle configuration centering on the optic axis AX in the entrance plane of the micro fly eye 8a via the zoom lens 7. As a result, the secondary light source which has the almost same light intensity distribution as the radiation field formed of the incoming beam, i.e., the secondary light source of the circle configuration centering on the optic axis AX, is formed in the backside focal plane (namely, pupil of an illumination-light study system) of the micro fly eye 8a.
[0131]In circular Lighting Sub-Division of a 2nd embodiment, the smallest secondary light source of a circle configuration formed by the normal condition changes to the secondary light source of the circle configuration to which the whole shape was expanded in similarity by making the focal distance of the zoom lens 7 expand from the minimum to a predetermined value. If it puts in another way, in circular Lighting Sub-Division of a 2nd embodiment, the size (outer diameter) of the secondary light source of a circle configuration can be changed by changing the focal distance of the zoom lens 7.
[0132]Drawing 24 is a figure explaining an operation of the 1st V groove axicon to the secondary light source formed in circular Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon. In circular Lighting Sub-Division of a 2nd embodiment, if the interval of the 1st V groove axicon 15 is expanded to a predetermined value from zero, as shown in drawing 24 (a), Among the surface light sources 66a-66d of four 4 semicircular state which constitute the secondary light source of a circle configuration, the surface light sources 66a and 66c move in the direction of -X, and the surface light sources 66b and 66d move them in the direction of +X.
[0133]On the other hand, if an interval of the 2nd V groove axicon 16 is expanded to a predetermined value from zero, as shown in drawing 24 (b), the surface light sources 66a and 66b will move to + Z direction, and will move the surface light sources 66c and 66d to - Z direction. If an interval of the 1st V groove axicon 15 and an interval of the 2nd V groove axicon 16 are expanded to a value predetermined [both] from zero, as shown in drawing 24 (c), The surface light source 66a moves in + Z direction and the direction of -X, the surface light source 66b moves in + Z direction and the direction of +X, the surface light source 66c moves in - Z direction and the direction of -X, and 66 d of surface light sources move it in - Z direction and the direction of +X. In this way, a secondary light source of the shape of 4 poles which consists of the four independent surface light sources of 4 semicircular state can be formed.
[0134]As mentioned above, although an operation of the 1st V groove axicon 15 in circular Lighting Sub-Division of a 2nd embodiment, the 2nd V groove axicon 16, and the zoom lens 7 was explained individually, circular Lighting Sub-Division of various forms is possible by an interaction of these optical members. However, a variable power range of an outer diameter by the zoom lens 7 has restriction by the restrictions on an optical design actually. So, in a 2nd embodiment, it has two kinds of diffraction optical elements from which the characteristic differs as the diffraction optical element 11c for circular Lighting Sub-Division.
[0135]That is, in a 2nd embodiment, the secondary light source of the circle configuration which has the form of having been suitable for changing a sigma value by a comparatively small sigma value, i.e., a sigma value interim from small sigma, i.e., the range to the inside sigma, is formed by one diffraction optical element for circular Lighting Sub-Division. The secondary light source of the circle configuration which has the form where it was suitable for changing a sigma value in the range from the inside sigma to a comparatively large sigma value, i.e., large sigma, by the diffraction optical element for circular Lighting Sub-Division of another side is formed. As a result, concomitant use of two kinds of diffraction optical elements for circular Lighting Sub-Division enables it to change a sigma value in the range (for example, 0.1<=sigma<=0.95) from small sigma to large sigma.
[0136]Hereafter, the switching operation of the Lighting Sub-Division conditions in a 2nd embodiment, etc. are explained concretely.

First, the information about various kinds of masks which should be exposed one by one according to a step-and-repeat system or a step and scanning method, etc. are inputted into the control system 21 via the input means 20 of a keyboard etc. The control system 21 has memorized information, including the optimal line width (resolution) about various kinds of masks, the depth of focus, etc., to the internal memory part, answers the input from the input means 20, and supplies the suitable control signal for the drive systems 24, 26-28.
[0137]namely, the basis of the optimal resolution and the depth of focus -- 4 -- when illuminating very much, the drive system 26 is based on the instructions from the control system 21 -- 4 -- the diffraction optical element 11a very for Lighting Sub-Division is positioned in a lighting optical path. And in order to obtain the secondary light source of the shape of 4 poles which has a desired form, the drive systems 28a-28c set up the interval of the axicons 14-16 based on the instructions from the control system 21, and the drive system 24 sets up the focal distance of the zoom lens 7 based on the instructions from the control system 21. The drive system 27 drives the variable aperture diaphragm of projection optical system PL based on the instructions from the control system 21.
[0138]By changing the interval of the axicons 14-16 by the drive systems 28a-28c, or changing the focal distance of the zoom lens 7 by the drive system 24 if needed, The form of the secondary light source of the shape of 4 poles formed in the backside focal plane of the micro fly eye 8a can be changed suitably. in this way -- changing suitably the size (outer diameter) of the secondary whole 4 pole-like light source and form (zona-orbicularis ratio), the position of each surface light source, form, a size, etc. -- various 4 -- it can illuminate very much.
[0139]When carrying out zona-orbicularis Lighting Sub-Division under the optimal resolution and the depth of focus, the drive system 26 positions the diffraction optical element 11b for zona-orbicularis Lighting Sub-Division in a lighting optical path based on the instructions from the control system 21. And in order to obtain the secondary light source of the shape of zona orbicularis which has a desired form, or in order to obtain the secondary 4 pole-like light source or the secondary 2 pole-like light source derivatively obtained from a secondary zona-orbicularis-like light source, and in order, The drive systems 28a-28c set up the interval of the axicons 14-16 based on the instructions from the control system 21, and the drive system 24 sets up the focal distance of the zoom lens 7 based on the instructions from the control system 21. The drive system 27 drives the variable aperture diaphragm of projection optical system PL based on the instructions from the control system 21.
[0140]By changing the interval of the axicons 14-16 by the drive systems 28a-28c, or changing the focal distance of the zoom lens 7 by the drive system 24 if needed, The form of the form of the secondary light source of the shape of zona orbicularis formed in the backside focal plane of the micro fly eye 8a, the secondary light source of the shape of 4 poles acquired derivatively, or a secondary 2 pole-like light source can be changed suitably. In this way, the size (outer diameter) of the secondary whole zona-orbicularis-like light source and form (zona-orbicularis ratio), the position of each surface light source acquired derivatively, form, a size, etc. can be changed suitably, and various zona-orbicularis Lighting Sub-Division can be performed.
[0141]When carrying out usual circular Lighting Sub-Division under the optimal resolution and the depth of focus, the drive system 26 positions the diffraction optical element 11c for circular Lighting Sub-Division in a lighting optical path based on the instructions from the control system 21. And in order to obtain the secondary light source of the circle configuration which has a desired form, or in order to obtain the secondary 4 pole-like light source or the secondary 2 pole-like light source derivatively obtained from the secondary light source of a circle configuration, and in order, The drive systems 28a-28c set up the interval of the axicons 14-16 based on the instructions from the control system 21, and the drive system 24 sets up the focal distance of the zoom lens 7 based on the instructions from the control system 21. The drive system 27 drives the variable aperture diaphragm of projection optical system PL based on the instructions from the control system 21.
[0142]By changing the interval of the axicons 14-16 by the drive systems 28a-28c, or changing the focal distance of the zoom lens 7 by the drive system 24 if needed, The form of the form of the secondary light source of the circle configuration formed in the backside focal plane of the micro fly eye 8a, the secondary light source of the shape of 4 poles acquired derivatively, or a secondary 2 pole-like light source can be changed suitably. In this way, the size (as a result, sigma value) of the whole secondary light source of a circle configuration, the position of each surface light source acquired derivatively, form, a size, etc. can be changed suitably, and various circular Lighting Sub-Division can be performed.
[0143]In a 2nd embodiment, although the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16 are arranged sequentially from the light source side, this arrangement order can also be changed suitably. Although the 1st prism component which has a concave refracting interface, and the 2nd prism that has a convex refracting interface are arranged sequentially from the light source side in each axicons 14-16, this arrangement order can also be made reverse.
[0144]Although each axicons 14-16 comprise a prism component of the couple at a 2nd embodiment, respectively, Without being limited to this unify the 2nd prism component 14b of the cone axicon 14, and the 1st prism component 15a of the 1st V groove axicon 15, for example, or, The 2nd prism component 15b of the 1st V groove axicon 15 and the 1st prism component 16a of the 2nd V groove axicon 16 can also be unified. In this case, by moving at least three components in accordance with the optic axis AX among the 2nd prism components 16b of the 1st prism component 14a of the cone axicon 14, two unified prism, and the 2nd V groove axicon 16, The interval of each axicons 14-16 can be changed independently, respectively.
[0145]Drawing 25 is a figure showing roughly composition of an exposure device provided with an illumination optical device concerning a 3rd embodiment of this invention. Drawing 26 is a perspective view showing roughly composition of a V groove axicon of a couple arranged in an optical path of an afocal lens in a 3rd embodiment. A 3rd embodiment has composition similar to a 2nd embodiment. However, in a 2nd embodiment, a point that only a V groove axicon of a couple is arranged is fundamentally different from a 2nd embodiment by a 3rd embodiment to a cone axicon and a V groove axicon of a couple being arranged in an optical path of the afocal lens 12. Hereafter, a 3rd embodiment is described paying attention to a point of difference with a 2nd embodiment.
[0146]In 4 pole Lighting Sub-Division of a 3rd embodiment, since a cone axicon is not arranged, a circle configuration of each surface light source which constitutes a secondary 4 pole-like light source cannot be changed to elliptical. However, while using selectively two or more diffraction optical elements 11a for 4 pole Lighting Sub-Division, in a circular field centering on the optic axis AX, a position of each surface light source can be suitably changed by using an operation of the 1st V groove axicon 15 and the 2nd V groove axicon 16. In a circular field centering on the optic axis AX, a position and a size of each surface light source can be suitably changed by using a variable power operation of the zoom lens 7 auxiliary.

[0147]On the other hand, in zona-orbicularis Lighting Sub-Division of a 3rd embodiment, since the cone axicon is not arranged, the zona-orbicularis ratio of a secondary zona-orbicularis-like light source cannot be changed continuously. However, while using selectively two or more diffraction optical elements 11b for zona-orbicularis Lighting Sub-Division, By using an operation of the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 7, The position, the form, and the size of each surface light source which constitutes the secondary 2 pole-like light source or the secondary 4 pole-like light source derivatively obtained from the secondary light source of the overall size and form (zona-orbicularis ratio) of a secondary zona-orbicularis-like light source, or the shape of zona orbicularis can be changed suitably.
[0148]By the way, in circular Lighting Sub-Division, an operation of a cone axicon is not used positively. Therefore, also in circular Lighting Sub-Division of a 3rd embodiment like the case of a 2nd embodiment, The position, the form, and the size of each surface light source which constitutes the secondary 2 pole-like light source or the secondary 4 pole-like light source derivatively obtained from the secondary light source of the overall size of the secondary light source of a circle configuration or a circle configuration can be changed suitably.
[0149]Drawing 27 is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 4th embodiment of this invention. Drawing 28 is a perspective view showing roughly the composition of the cone axicon arranged in the optical path of an afocal lens in a 4th embodiment, and the 1st V groove axicon. A 4th embodiment has composition similar to a 2nd embodiment. However, in a 2nd embodiment, the point that only the cone axicon and the 1st V groove axicon are arranged is fundamentally different from a 2nd embodiment by a 4th embodiment to the cone axicon and the V groove axicon of a couple being arranged in the optical path of the afocal lens 12. Hereafter, a 4th embodiment is described paying attention to a point of difference with a 2nd embodiment. In drawing 27 and drawing 28, although the 1st V groove axicon 15 is shown as one V groove axicon, one V groove axicon may be the 2nd V groove axicon 16.
[0150]In 4 pole Lighting Sub-Division of a 4th embodiment, since only one V groove axicon (15 or 16) is arranged, it cannot change only the position in two dimensions, with form and a size of each surface light source of a circle configuration maintained which constitute a secondary 4 pole-like light source. However, while using selectively two or more diffraction optical elements 11a for 4 pole Lighting Sub-Division, In a circular field centering on the optic axis AX, a position, form, and a size of each surface light source can be suitably changed by using the cone axicon 14, one V groove axicon (15 or 16), and an operation of the zoom lens 7.
[0151]On the other hand, in zona-orbicularis Lighting Sub-Division of a 4th embodiment, since only one V groove axicon (15 or 16) is arranged, a secondary 4 pole-like light source cannot be derivatively obtained from a secondary zona-orbicularis-like light source. However, while using selectively two or more diffraction optical elements 11b for zona-orbicularis Lighting Sub-Division, By using the cone axicon 14, one V groove axicon (15 or 16), and an operation of the zoom lens 7, A position, form, and a size of each surface light source which constitutes a secondary light source of the shape of 2 poles derivatively acquired from a secondary light source of an overall size and form (zona-orbicularis ratio) of a secondary zona-orbicularis-like light source, or the shape of zona orbicularis can be changed suitably.
[0152]In circular Lighting Sub-Division of a 4th embodiment, since only one V groove axicon (15 or 16) is arranged, a secondary 4 pole-like light source cannot be derivatively obtained from the secondary light source of a circle configuration. However, while using selectively two or more diffraction optical elements 11c for circular Lighting Sub-Division, By using the cone axicon 14, one V groove axicon (15 or 16), and an operation of the zoom lens 7, The position, the form, and the size of each surface light source which constitutes the secondary light source of the shape of 2 poles derivatively acquired from the secondary light source of the overall size of the secondary light source of a circle configuration or a circle configuration can be changed suitably.
[0153]Drawing 29 is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 5th embodiment of this invention. A 5th embodiment has composition similar to a 2nd embodiment. However, in a 5th embodiment, it replaces with a wavefront-splitting type optical integrator (micro fly eye 8a), and the point of using the internal reflection type optical integrator (rod type integrator 70) is fundamentally different from a 2nd embodiment. Hereafter, a 5th embodiment is described paying attention to a point of difference with a 2nd embodiment.
[0154]It responds to having replaced with the micro fly eye 8a, and arranging the rod type integrator 70 in a 5th embodiment, In the optical path between the diffraction optical element 11 and the rod type integrator 70, the zoom lens 71, the 2nd diffraction optical element (or micro fly eye) 72, and the input lens 73 are arranged sequentially from the light source side. The mask blinds 17 as a lighting field diaphragm are arranged near the projection surface of the rod type integrator 70.
[0155]Here, the zoom lens 71 is arranged so that the rear side focal position of the front side focal position may correspond with the position of the 2nd diffraction optical element 72 mostly almost in accordance with the position of the diffraction optical element 11. Change of the focal distance of the zoom lens 71 is performed by the drive system 29 which operates based on the instructions from the control system 21. The input lens 73 is arranged so that the rear side focal position of the front side focal position may correspond with the position of the entrance plane of the rod type integrator 70 mostly almost in accordance with the position of the 2nd diffraction optical element 72.
[0156]The rod type integrator 70 is an internal reflection type glass rod which consists of glass material like silica glass or fluorite, and forms the light source image of the number according to the number of internal reflection along a field parallel to a rod entrance plane through a condensing point using total internal reflection, the interface, i.e., the inner surface, of an inside and the exterior. Here, although most light source images formed are virtual images, only a main (condensing point) light source image turns into a real image. That is, the light flux which entered into the rod type integrator 70 is divided into angular orientation by internal reflection, and the secondary light source which consists of many light source images along a field parallel to the entrance plane through a condensing point is formed.
[0157]Therefore, in 4 pole Lighting Sub-Division (zona-orbicularis Lighting Sub-Division or circular Lighting Sub-Division) of a 5th embodiment, the light flux which passed the diffraction optical element 11a (11b or 11c) selectively installed in the lighting optical path forms a 4 pole-like (shape of zona orbicularis, or circle configuration) radiation field on the 2nd diffraction optical element 72 via the zoom lens 71. The light flux which passed the 2nd diffraction optical element 72 condenses near the entrance plane of the rod type integrator 70 via the input lens 73. Drawing 30 is a figure explaining an operation of the 2nd diffraction optical element in a 5th embodiment.
[0158]As shown in drawing 30 (a), when the 2nd diffraction optical element 72 is not arranged, on the entrance plane 70a of the rod

type integrator 70, the light flux through the zoom lens 71 and the input lens 73 condenses to about one point. The light source of a large number formed in the incidence side by the rod type integrator 70 will become very in loss (the filling factor of each light source to the whole secondary light source becoming small), and it will become impossible as a result, to acquire the substantial surface light source.

[0159]So, in a 5th embodiment, the 2nd diffraction optical element 72 as a light flux emission element is arranged near the front side focal position of the input lens 73. In this way, as shown in drawing 30 (b), the light flux emitted via the 2nd diffraction optical element 72 passes the input lens 73, and condenses with predetermined breadth on the entrance plane 70a of the rod type integrator 70. As a result, the light source of a large number formed in the incidence side by the rod type integrator 70 becomes very dense (the filling factor of each light source to the whole secondary light source becoming large), and the secondary light source as the substantial surface light source can be obtained.

[0160]The light flux from the secondary light source of the shape of 4 poles formed in the incidence side by the rod type integrator 70 (the shape of zona orbicularis or circle configuration) illuminates the mask M in which the predetermined pattern was formed via the mask blinds 17 and the image formation optical system 18, after being superimposed in the projection surface. In a 5th embodiment, the cone axicon 14, the 1st V groove axicon 15, and the 2nd V groove axicon 16 are arranged sequentially from the light source side in the optical path between the front side lens group 71a of the zoom lens 71, and the back side lens group 71b.

[0161]Therefore, while using selectively two or more diffraction optical elements 11a for 4 pole Lighting Sub-Division like a 2nd embodiment also in 4 pole Lighting Sub-Division of a 5th embodiment, In the circular field centering on the optic axis AX, the position, the form, and the size of each surface light source which constitutes a secondary zona-orbicularis-like light source can be suitably changed by using an operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 71.

[0162]While using selectively two or more diffraction optical elements 11b for zona-orbicularis Lighting Sub-Division like a 2nd embodiment also in zona-orbicularis Lighting Sub-Division of a 5th embodiment, By using an operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 71, The position, the form, and the size of each surface light source which constitutes the secondary 2 pole-like light source or the secondary 4 pole-like light source derivatively obtained from the secondary light source of the overall size and form (zona-orbicularis ratio) of a secondary zona-orbicularis-like light source, or the shape of zona orbicularis can be changed suitably.

[0163]While using selectively two or more diffraction optical elements 11c for circular Lighting Sub-Division like a 2nd embodiment also in circular Lighting Sub-Division of a 5th embodiment, By using an operation of the cone axicon 14, the 1st V groove axicon 15, the 2nd V groove axicon 16, and the zoom lens 71, The position, the form, and the size of each surface light source which constitutes the secondary 2 pole-like light source or the secondary 4 pole-like light source derivatively obtained from the secondary light source of the overall size of the secondary light source of a circle configuration or a circle configuration can be changed suitably.

[0164]As mentioned above, also in a 2nd embodiment - a 5th embodiment, the size and form of the whole secondary light source change to the direction of X, or a Z direction by changing the interval of the V groove axicon 15 or 16. As a result, the Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on the mask M which can realize Lighting Sub-Division conditions which are mutually different for the two way types with which it intersects perpendicularly on the mask M (the direction of X and the direction of Y), and has directivity in a pattern by extension can be set up.

[0165]Especially a 3rd embodiment provided only with the V groove axicons 15 and 16 of a couple as a variable means among a 2nd above-mentioned embodiment - a 5th embodiment is suitable for the lithography step of memories (DRAM etc.). Especially a 4th embodiment provided only with the cone axicon 14 and one V groove axicon (15 or 16) as a variable means is suitable for the lithography step of logic devices (MPU etc.). A 2nd embodiment and a 5th embodiment which were provided with the cone axicon 14 and the V groove axicons 15 and 16 of a couple as a variable means are suitable for the lithography step of the common micro device containing a semiconductor device.

[0166]By the way, although an above embodiment [5th] (see drawing 29) explained the example which made the optical integrator arranged at the mask side of an axicon system (14, 15, 16) the internal reflection type optical integrator (rod type optical integrator) 70, It cannot be overemphasized that the fly eye lens 8 and the micro fly eye 8a as an optical integrator mentioned above can be replaced with the internal reflection type optical integrator (rod type optical integrator) 70, either.

[0167]Although the direction of a V groove of the 1st V groove axicon 15 was made into a Z direction (the direction of 0 degree) and an example which made the direction of a V groove of the 2nd V groove axicon 16 the direction (the direction of 90 degree) of X was shown by above embodiment [2nd], 3rd embodiment, and a 5th embodiment (see drawing 10, drawing 25, and drawing 29), This invention is not limited to this arrangement and makes the direction of a V groove of the 1st V groove axicon 15 a direction (the direction of 45 degree) clockwise rotated 45 degrees to an optical axis center, for example, The direction of a V groove of the 2nd V groove axicon 16 can be carried out in the direction (the direction of 135 degree) etc. which were clockwise rotated 45 degrees to an optical axis center. A shadow of a slot which enters into the micro fly eye 8a serves as slant by this, and an effect that illumination unevenness can be reduced can be expected. According to Lighting Sub-Division conditions expected an angle (crossed axes angle) of the direction of a V groove of the 1st V groove axicon 15, and the direction of a V groove of the 2nd V groove axicon 16 to make, it can change arbitrarily. In order to change a crossed axes angle of a slot of two V groove axicons like the above, The control system 21 makes at least one side of the drive system 28b and the drive system 28c drive based on input inputted via the input means 20, and should just rotate relatively to an optical axis center the 1st V groove axicon 15 and the 2nd V groove axicon 16.

[0168]Although an above embodiment [4th] (see drawing 27) showed the example which made the direction of the V groove of the V groove axicon 15 the Z direction (the direction of 0 degree), This invention is not limited to this arrangement and can carry out the direction of the V groove of the V groove axicon 15 in the direction (the direction of 45 degree) rotated 45 degrees to the optical axis center, the direction (the direction of 90 degree) rotated 90 degrees, the direction (the direction of 135 degree) rotated 135 degrees, etc., for example. That is, according to the Lighting Sub-Division conditions expected the direction of the V groove of the V groove axicon 15, it can change arbitrarily. In order to change the direction of the slot of a V groove axicon like the above, the drive system 28b is made to drive based on the input inputted via the input means 20, and only a predetermined rotation should make an optical axis center, as for the control system 21, rotate the V groove axicon 15.

[0169]Although it is preferred in each above embodiment to set the variable range of a sigma value to 0.1 to 0.95 (0.1<=sigma<=0.95) by concomitant use with a diffraction optical element (11a, 11b, 11c) and the zoom lens 7 (variable power optical system) for sigma

value variable, If restrictions of the lens number of sheets which constitutes the zoom lens 7 (variable power optical system) for sigma value variable, the space of that, etc. are canceled, the range of the sigma value of 0.1-0.95 demanded as equipment can be continuously made variable.

[0170]As for zona-orbicularis light flux formed in a pupil (pupil of a projection optical system) of an illumination-light study system, in zona-orbicularis Lighting Sub-Division in the above 1st embodiment - 5th embodiment, it is desirable to make a zona-orbicularis ratio variable within the range of a sigma value of 0.4-0.95 (0.4<=sigma<=0.95). Multi-electrode-like light flux formed in a pupil (pupil of a projection optical system) of an illumination-light study system in 2 pole Lighting Sub-Division in the above 1st embodiment - 5th embodiment, or multi-electrode Lighting Sub-Division including 4 pole Lighting Sub-Division, It is desirable to make a position and a size variable within the range of a sigma value of 0.4-0.95 (0.4<=sigma<=0.95).

[0171]In order to measure aberration which remains in projection optical system PL, or aberration (wavefront aberration etc.) which change temporally in the above 1st embodiment - 5th embodiment, For example, a mask for aberration Measurement Division (reticle for aberration Measurement Division) currently indicated by US,5,828,455,B, US,5,978,085,B, etc. is laid in mask stage MS which is not illustrated holding the mask (reticle) M, By carrying out suitable Lighting Sub-Division to the mask for aberration Measurement Division, it is possible to measure aberration (wavefront aberration etc.) of projection optical system PL with high precision. Here, as a result of having advanced research for Lighting Sub-Division conditions which can measure aberration (wavefront aberration etc.) of projection optical system PL with high precision from various angles, it became clear that it was preferred to set up a sigma value of an illumination-light study system for any of the range of 0.01<=sigma<=0.3 being. In order to measure aberration (wavefront aberration etc.) of projection optical system PL much more with high precision, it is much more preferred to set up a sigma value of an illumination-light study system for any of the range of 0.02<=sigma<=0.2 being. Thus, in order to set Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3, or the range of 0.02<=sigma<=0.2, a sigma value of an illumination-light study system, What is necessary is just to set up a diffraction optical element for Measurement Division which sets up the minimum sigma value instead of a diffraction optical element (11a, 11b, 11c) which constitutes a part of Lighting Sub-Division conditioning means (4a, 4b, 5, 7, 10, 11a-11c, 12, 14-16, 71, 71a) in each above embodiment. When aberration has occurred in projection optical system PL of an above embodiment [1st] - a 5th embodiment, Input measured aberration information into the input means 20, and the control system 21, Based on aberration information inputted via the input means 20, for example, via an unillustrated drive system, By moving at least one optical elements (a lens, a mirror, etc.) which constitute projection optical system PL (it rotates to a circumference of an inclination and an optic axis to movement of an optical axis direction of projection optical system PL, movement of a direction which intersects perpendicularly with an optic axis, and an optic axis), Aggravation of optical properties including aberration of projection optical system PL can be amended.

[0172]When the equipment shown in the above 1st embodiment - 5th embodiment is used as a scanning type exposure device, An illumination-light study system a slit shape (rectangular form which has the transverse direction and a longitudinal direction) illuminated field (illuminated field which has the transverse direction in the direction of space or scanning direction of drawing 1, drawing 10, drawing 25, drawing 27, and drawing 29) on the mask M, The mask which formed the slit shape exposure region on the wafer W, and was held at unillustrated mask stage MS, By moving the wafer (substrate) held at unillustrated wafer stage (substrate stage) WS to for opposite along a scanning direction (drawing 1, drawing 10, drawing 25, drawing 27, and the direction of space of drawing 29), the pattern image of the mask M is formed on the wafer W via projection optical system PL. In this case, unillustrated mask stage MS and unillustrated wafer stage (substrate stage) WS are controlled by the control system 21 via the drive which makes each unillustrated stage drive.

[0173]In the equipment shown in each above embodiment, each sectional shape of the optical element (lens element) of a large number which constitute the fly eye lens (array form optical element) 8 and the micro fly eye (microarray-like optical element) 8a as an optical integrator, It is preferred to consider it as the slit shape (rectangular form which has the transverse direction and a longitudinal direction) illuminated field formed on the mask M and the exposure region of the slit shape (rectangular form which has the transverse direction and a longitudinal direction) formed on the wafer W, and similarity.

[0174]As shown in each above embodiment, In the case of the scanning type exposure device which transposed the fly eye lens (array form optical element) 8 and the micro fly eye (microarray-like optical element) 8a as an optical integrator to the internal reflection type optical integrator (rod type optical integrator). In and the case of the scanning type exposure device which made the optical integrator the internal reflection type optical integrator (rod type optical integrator) like a 5th embodiment. The sectional shape of an internal reflection type optical integrator (rod type optical integrator), It is preferred to consider it as the slit shape (rectangular form which has the transverse direction and a longitudinal direction) illuminated field formed on the mask M and the exposure region of the slit shape (rectangular form which has the transverse direction and a longitudinal direction) formed on the wafer W, and similarity.

[0175]Maintaining an efficient large view, when the equipment shown in each above embodiment is used as a scanning type exposure device without causing enlargement and complication of projection optical system PL. In order to attain the scanning exposure under a high throughput, When setting to Ls the length of the transverse direction in the slit shape illuminated field (or slit shape exposure region formed on the wafer W) formed on the mask M and setting the length of the longitudinal direction of the illuminated field to Ll, it is preferred to fill the relation of 0.05<Ls/Ll<0.7. In the scanning type exposure device shown in each above embodiment, it is being referred to as Ls/Ll=1/3, for example.

[0176]By what (exposure process) the pattern for transfer which illuminated the mask (reticle) (Lighting Sub-Division process), and was formed in the mask in the exposure device concerning each above-mentioned embodiment using the projection optical system by the illumination optical device is exposed for to a photosensitive substrate. Micro devices (a semiconductor device, an image sensor, a liquid crystal display element, a thin film magnetic head, etc.) can be manufactured. Hereafter, by forming a predetermined circuit pattern in the wafer as a photosensitive substrate, etc. using the exposure device of each above-mentioned embodiment explains with reference to the flow chart of drawing 8 per example of the technique at the time of obtaining the semiconductor device as a micro device.

[0177]First, in Step 301 of drawing 8, a metal membrane is vapor-deposited on the wafer of one lot. In the following step 302, photoresist is applied on the metal membrane on the wafer of the l lot. Then, in Step 303, exposure transfer of the image of the pattern on a mask is carried out to each shot region on the wafer of the one lot one by one via the projection optical system using

the exposure device of each above-mentioned embodiment. Then, in the step 305 after development of the photoresist on the wafer of the one lot was performed in Step 304, By etching by using a resist pattern as a mask on the wafer of the one lot, the circuit pattern corresponding to the pattern on a mask is formed in each shot region on each wafer. Then, devices, such as a semiconductor device, are manufactured by performing formation of the circuit pattern of the upper layer, etc. According to the above-mentioned semiconductor device manufacturing method, the semiconductor device which has a very detailed circuit pattern can be obtained with a sufficient throughput.

[0178]In the exposure device of each above-mentioned embodiment, the liquid crystal display element as a micro device can also be obtained by forming predetermined patterns (a circuit pattern, an electrode pattern, etc.) on a plate (glass substrate). Hereafter, with reference to the flow chart of drawing 9, it explains per example of the technique at this time. In drawing 9, what is called an optical lithography process of carrying out transfer exposure of the pattern of a mask to photosensitive substrates (glass substrate etc. in which the resist was applied) using the exposure device of each above-mentioned embodiment is performed by the pattern formation process 401. Of this optical lithography process, the prescribed pattern containing many electrodes etc. is formed on a photosensitive substrate. Then, by passing through each process, such as a developing process, an etching step, and a reticle peeling process, a predetermined pattern is formed on a substrate and the exposed substrate shifts to the following light filter formation process 402.

[0179]Next, in the light filter formation process 402: Many groups of three dots corresponding to R (Red), G (Green), and B (Blue) are arranged by matrix form, or form the light filter which arranged the group of three filters, R, G, and B, of a stripe to two or more horizontal scanning line directions. And 403 is performed for a cell assembler after the light filter formation process 402. By 403, a liquid crystal panel (liquid crystal cell) is assembled as a cell assembler using the substrate which has the prescribed pattern obtained by the pattern formation process 401, the light filter obtained with the light filter formation process 402, etc. In 403, a liquid crystal is poured in as a cell assembler between the substrate which has the prescribed pattern obtained by the pattern formation process 401, for example, and the light filter obtained with the light filter formation process 402, and he manufactures a liquid crystal panel (liquid crystal cell).

[0180]Then, you attach each part articles in which the display action of the assembled liquid crystal panel (liquid crystal cell) is made to perform, such as an electric circuit and a back light, as a module assembler, and he makes it complete as a liquid crystal display element in 404. According to the manufacturing method of an above-mentioned liquid crystal display element, the liquid crystal display element which has a very detailed circuit pattern can be obtained with a sufficient throughput.

[0181]Although the secondary light source of the shape of 4 poles or the shape of zona orbicularis is formed in illustration in deformation illumination in each above-mentioned embodiment, The secondary light source of the shape what is called of plural poles or the shape of a multi-electrode like the secondary light source of the shape of 2 poles which consists of the two surface light sources which carried out eccentricity to the optic axis, and the secondary light source of the shape of 8 poles which consists of the eight surface light sources which carried out eccentricity to the optic axis can also be formed.

[0182]Although each above-mentioned embodiment explained this invention taking the case of the projection aligner provided with the illumination optical device, it is clear that this invention is applicable to the common illumination optical device for illuminating irradiated planes other than a mask.

[0183]

[Effect of the Invention]As explained above, in order to change the degree of incidence angle along the prescribed direction of the incoming beam to an optical integrator, with the illumination optical device of this invention, it has the aspect ratio change element which changes the aspect ratio of an incoming beam. Therefore, Lighting Sub-Division conditions which are mutually different for the two way types with which the size of the whole secondary light source can be changed along a prescribed direction, and it intersects perpendicularly on an irradiated plane by extension by operation of this aspect ratio change element are realizable.

[0184]Therefore, in the exposure device incorporating the illumination optical device of this invention, the Lighting Sub-Division conditions optimal for two way types of intersecting perpendicularly on the mask which has directivity in a pattern can be set up, and a good micro device can be manufactured under good Lighting Sub-Division conditions. This invention can transfer the pattern of a mask correctly under relevant Lighting Sub-Division conditions, and simultaneously, although the pattern of a mask is transferred correctly, it faces it, An exposure device, an exposure method, etc. which can check the optical performance of a projection optical system with high degree of accuracy can be realized, and a still better micro device can be manufactured.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 1st embodiment of this invention.
[Drawing 2]It is a figure showing roughly the composition of the secondary light source of the shape of 4 poles formed in the backside focal plane of a fly eye lens.
[Drawing 3]It is a figure showing roughly the composition of the prism of the couple which constitutes the V groove axicon arranged in the optical path of an afocal zoom lens.
[Drawing 4]Change of the interval of a V groove axicon, change of the magnification of an afocal zoom lens, and change of the focal distance of a zoom lens are the figures which illustrate typically the influence which it has on a secondary 4 pole-like light source.
[Drawing 5]Change of the interval of a V groove axicon, change of the magnification of an afocal zoom lens, and change of the focal distance of a zoom lens are the figures which illustrate typically the influence which it has on a secondary zona-orbicularis-like light source.
[Drawing 6]It is a figure showing the modification about the refracting interface form of a V groove axicon.
[Drawing 7]It is a figure showing the modification about rotation of a V groove axicon and combination.
[Drawing 8]It is a flow chart of the technique at the time of obtaining the semiconductor device as a micro device.
[Drawing 9]It is a flow chart of the technique at the time of obtaining the liquid crystal display element as a micro device.
[Drawing 10]It is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 2nd embodiment of this invention.
[Drawing 11]It is a perspective view showing roughly the composition of three axicons arranged in a 2nd embodiment in the optical path between the front side lens group of an afocal lens, and a back side lens group.
[Drawing 12]It is a figure explaining an operation of the cone axicon to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment.
[Drawing 13]It is a figure explaining an operation of the zoom lens to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment.
[Drawing 14]It is a figure explaining an operation of the 1st V groove axicon to the secondary light source formed in 4 pole Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon.
[Drawing 15]It is a figure explaining an operation of the cone axicon to each surface light source of the circle configuration formed in 4 pole Lighting Sub-Division of a 2nd embodiment, a zoom lens, the 1st V groove axicon, and the 2nd V groove axicon.
[Drawing 16]It is a figure explaining each surface light source formed via three kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in a 2nd embodiment, and its moving range.
[Drawing 17]It is a figure explaining each surface light source formed via four kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in the 1st modification of a 2nd embodiment, its movement, and modification.
[Drawing 18]It is a figure explaining each surface light source formed via four kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in the 1st modification of a 2nd embodiment, its movement, and modification.
[Drawing 19]It is a figure explaining each surface light source formed via two kinds of diffraction optical elements for 4 pole Lighting Sub-Division from which the characteristic differs in the 2nd modification of a 2nd embodiment, its movement, and modification.
[Drawing 20]It is a figure explaining an operation of the cone axicon to the secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment.
[Drawing 21]It is a figure explaining an operation of the zoom lens to the secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment.
[Drawing 22]It is a figure explaining an operation of the 1st V groove axicon to the secondary light source formed in zona-orbicularis Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon.
[Drawing 23]It is a figure explaining the 3rd modification of a 2nd embodiment.
[Drawing 24]It is a figure explaining an operation of the 1st V groove axicon to the secondary light source formed in circular Lighting Sub-Division of a 2nd embodiment and the 2nd V groove axicon.
[Drawing 25]It is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 3rd embodiment of this invention.
[Drawing 26]It is a perspective view showing roughly the composition of the V groove axicon of the couple arranged in the optical path of an afocal lens in a 3rd embodiment.
[Drawing 27]It is a figure showing roughly the composition of the exposure device provided with the illumination optical device concerning a 4th embodiment of this invention.
[Drawing 28]It is a perspective view showing roughly the composition of the cone axicon arranged in the optical path of an afocal lens in a 4th embodiment, and the 1st V groove axicon.
[Drawing 29]It is a figure showing roughly the composition of the exposure device provided with the illumination optical device

concerning a 5th embodiment of this invention.
[Drawing 30]It is a figure explaining an operation of the 2nd diffraction optical element in a 5th embodiment.
[Explanations of letters or numerals]
1 Light source
4 Diffraction optical element
5 Afocal zoom lens
6 Micro fly eye
7 Zoom lens
8 Fly eye lens
8a Micro fly eye
9 Condenser optical systems
10 V groove axicon
11 and 72 Diffraction optical element
12 Afocal lens
14 Cone axicon
15, 16 V-groove axicon
17 Mask blinds
18 Image formation optical system
70 Rod type integrator
71 Zoom lens
73 Input lens
M Mask
PL Projection optical system
W Wafer
20 Input means
21 Control system
22-29 Drive system

[Translation done.]

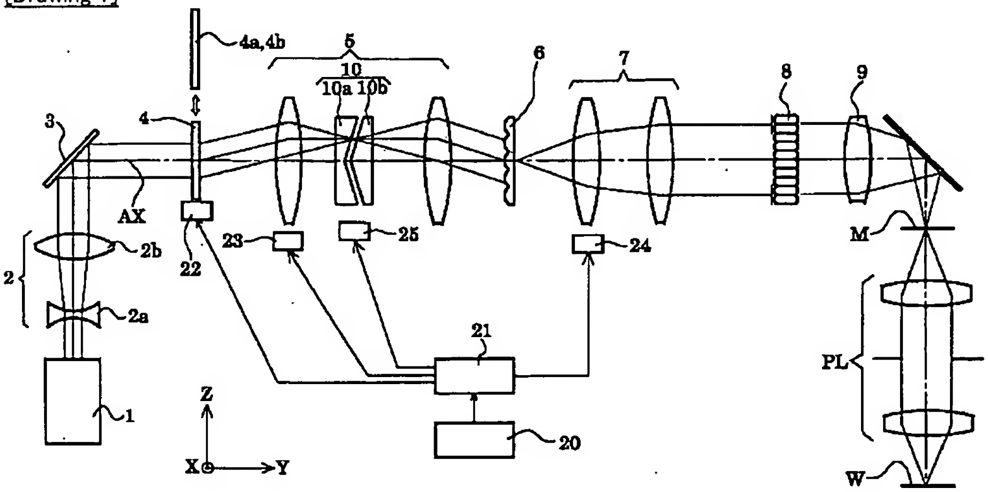
* NOTICES *

JPO and INPIT are not responsible for any
damages caused by the use of this translation.

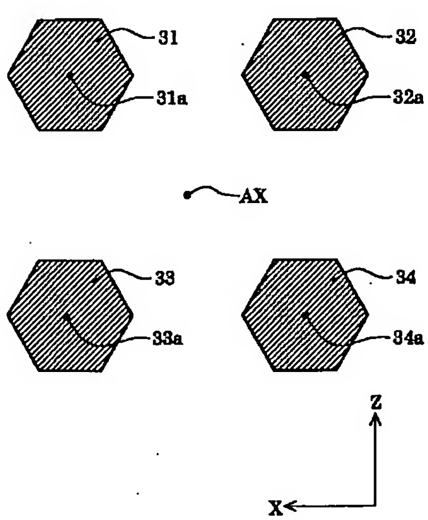
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 1]

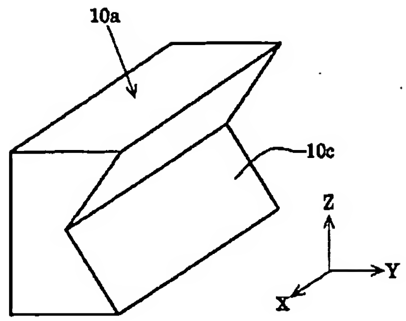


[Drawing 2]

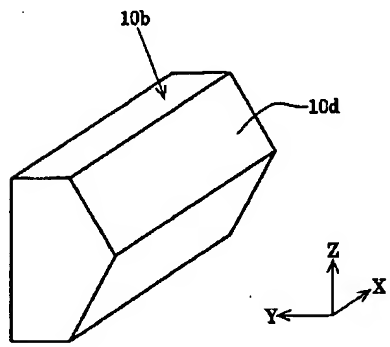


[Drawing 3]

(a)

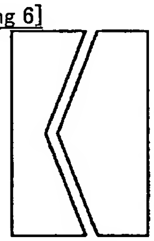


(b)



[Drawing 6]

(a)



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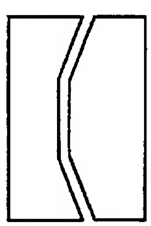
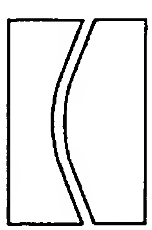
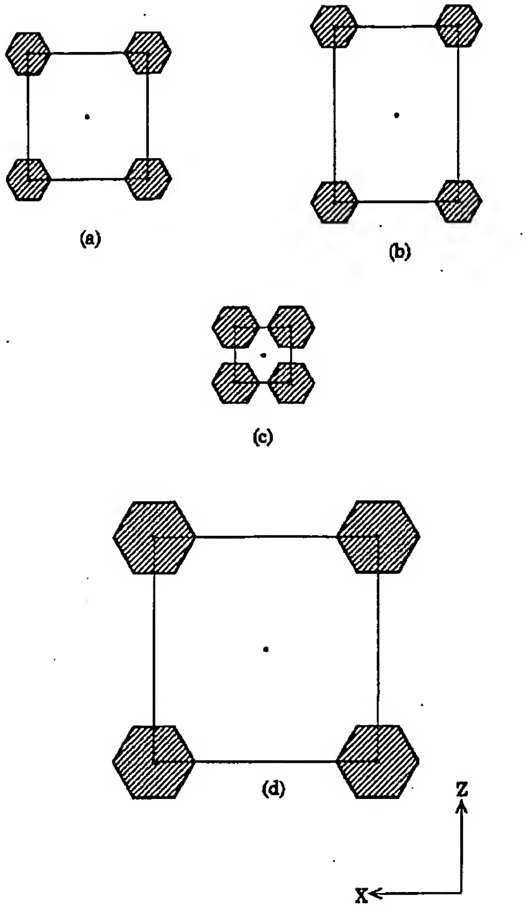


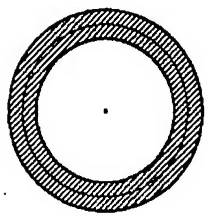
(c)



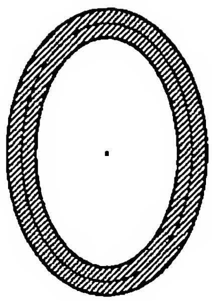
[Drawing 4]



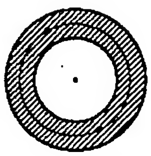
[Drawing 5]



(a)



(b)



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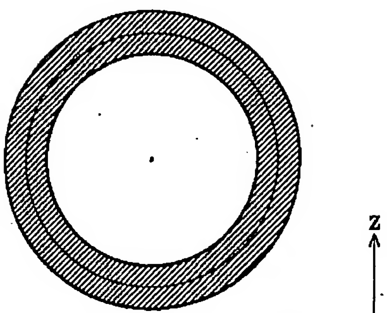
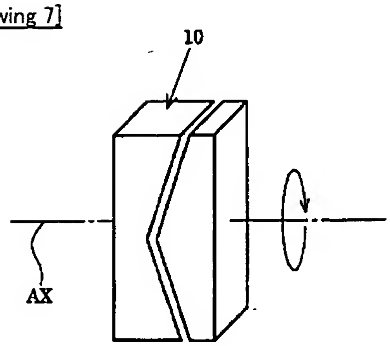


(d)

[Drawing 7]



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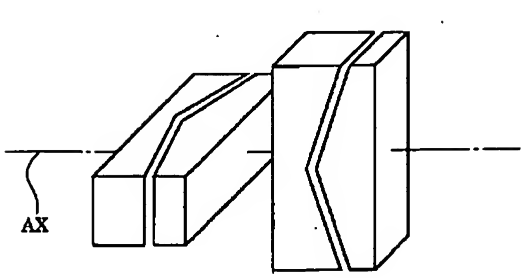
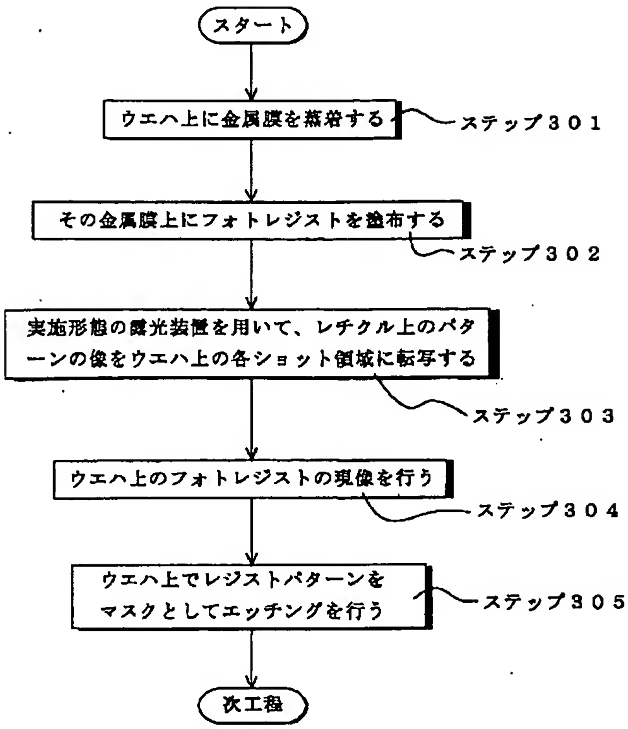
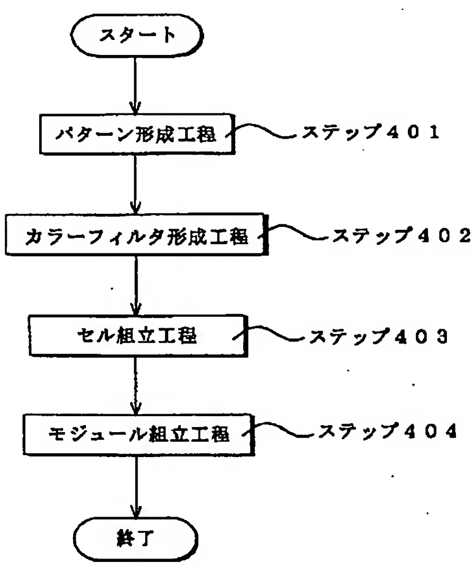


(b)

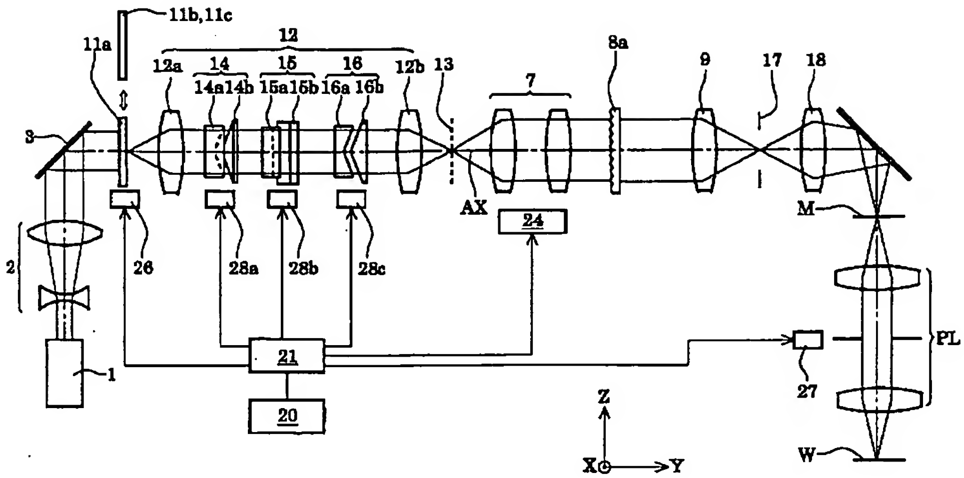
[Drawing 8]



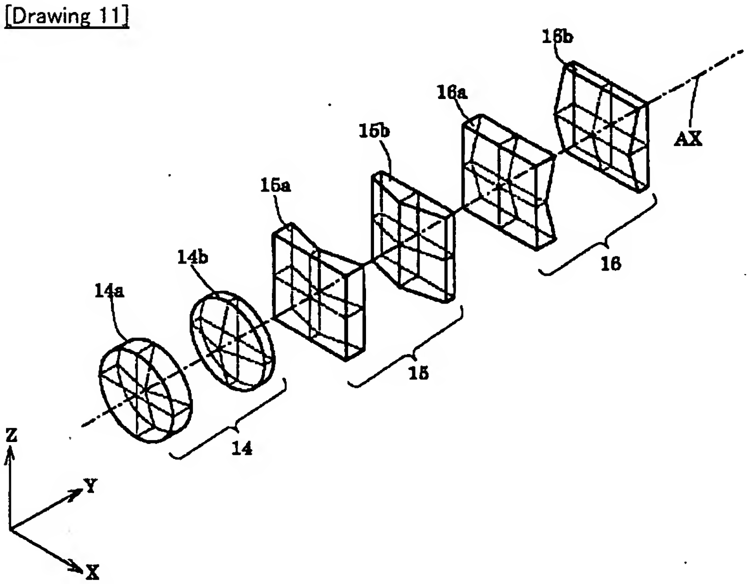
[Drawing 9]



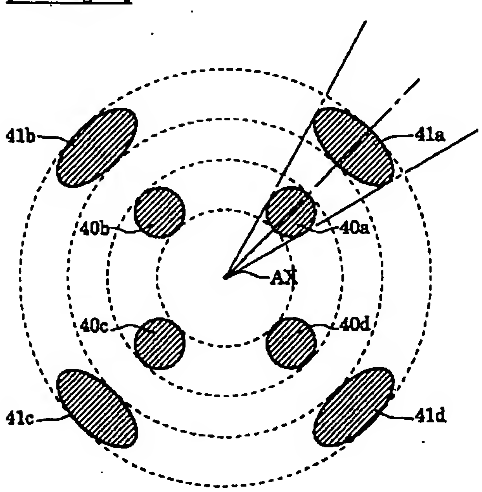
[Drawing 10]



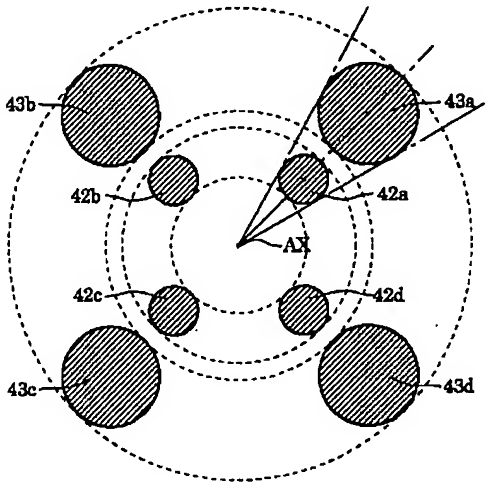
[Drawing 11]



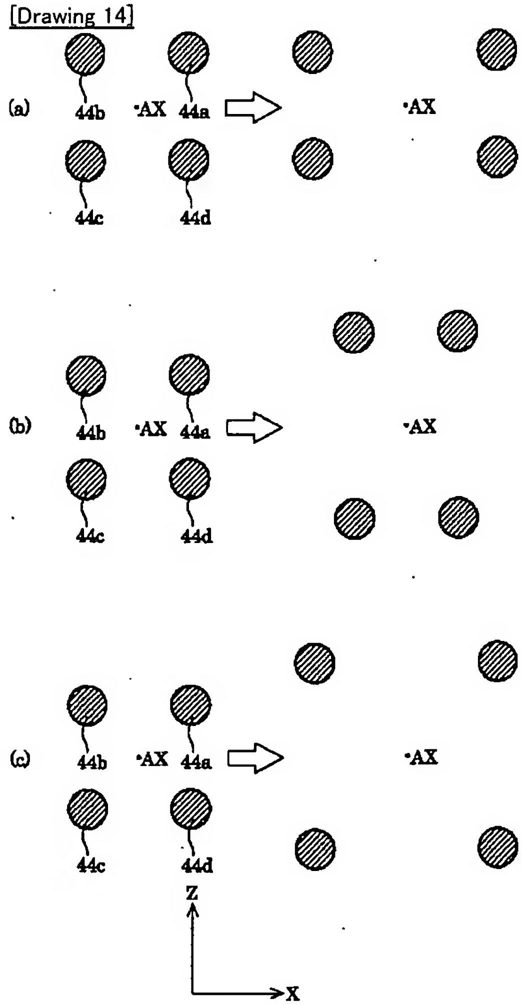
[Drawing 12]



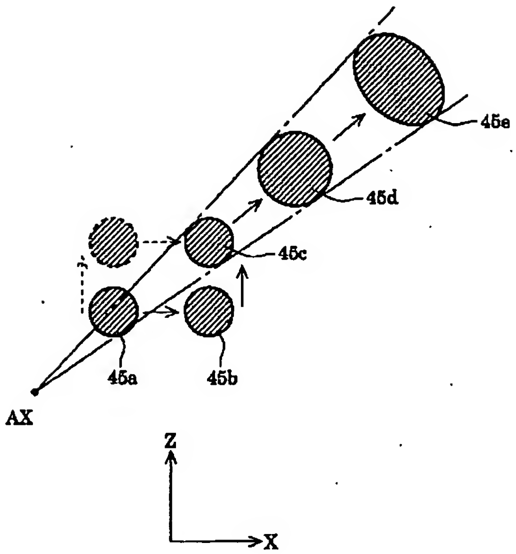
[Drawing 13]



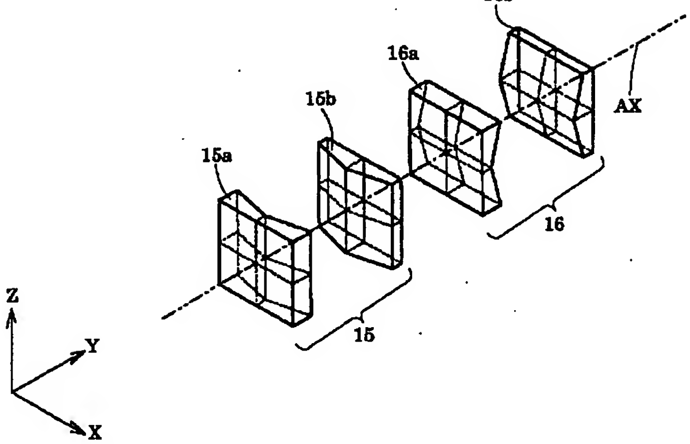
[Drawing 14]



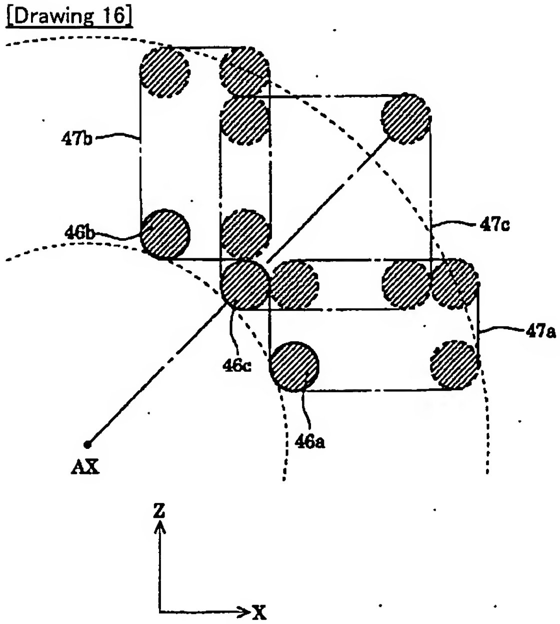
[Drawing 15]



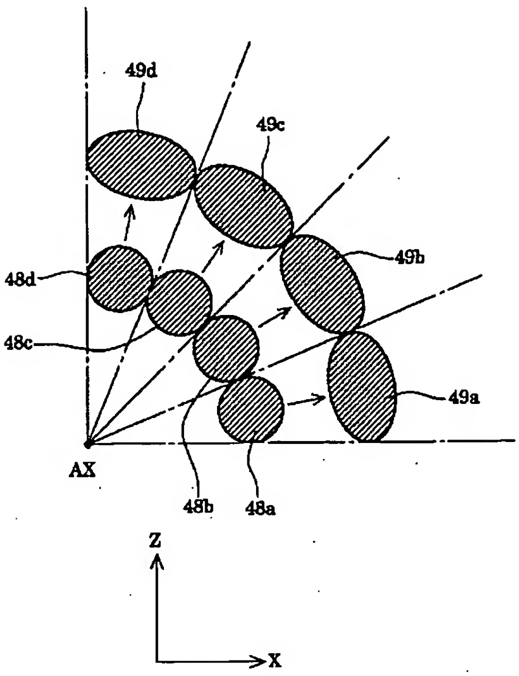
[Drawing 26]



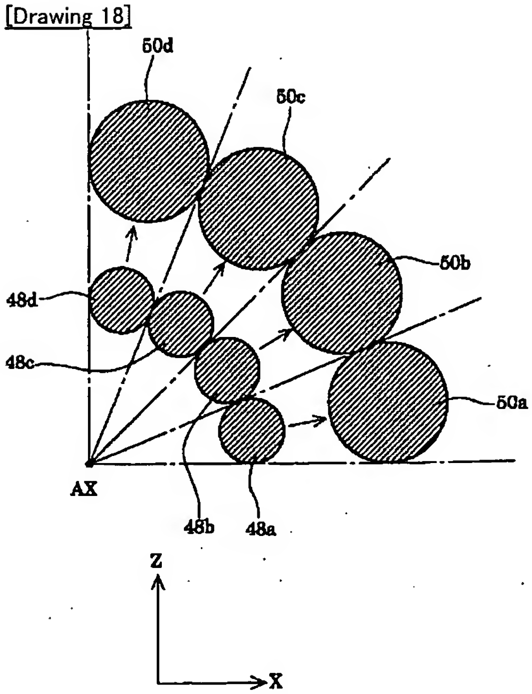
[Drawing 16]



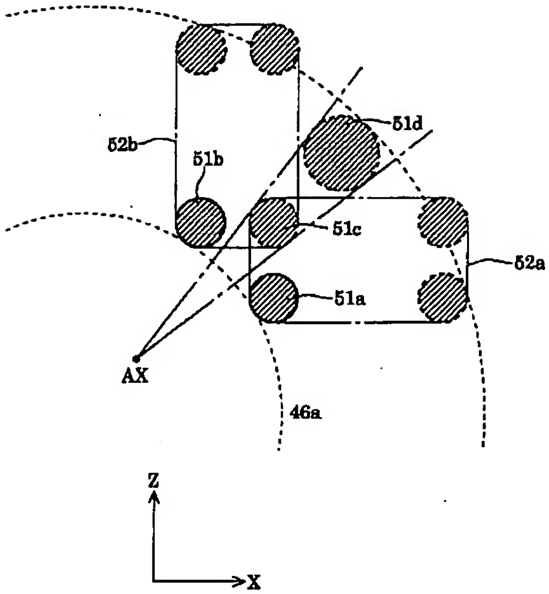
[Drawing 17]



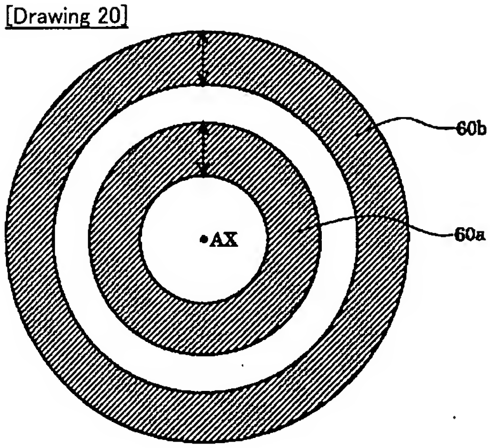
[Drawing 18]



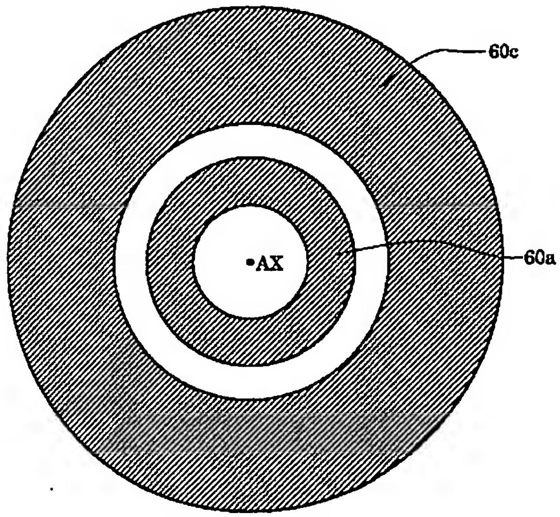
[Drawing 19]



[Drawing 20]

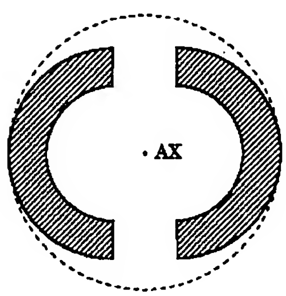


[Drawing 21]



[Drawing 23]

(a)



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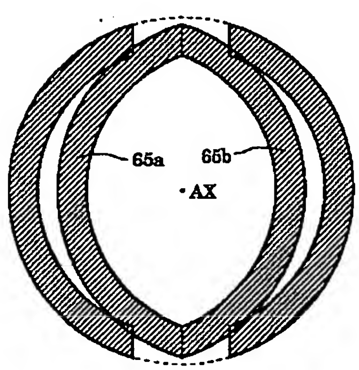
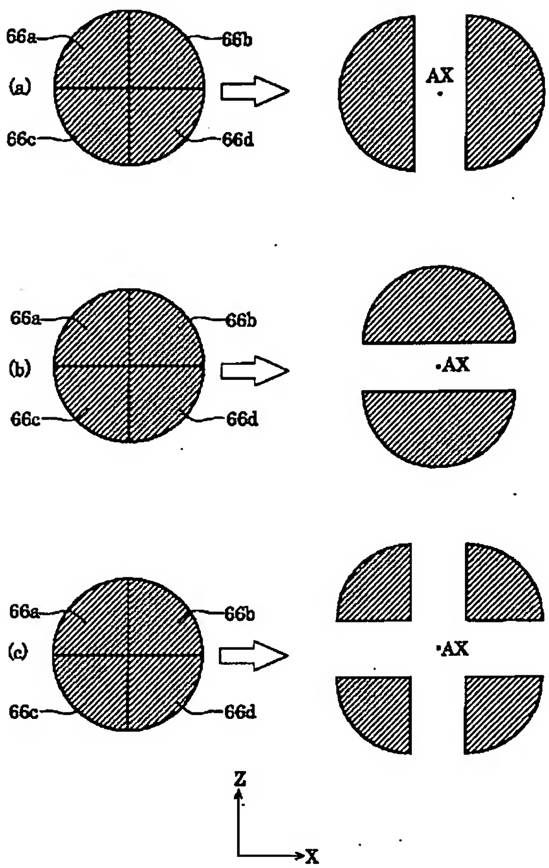
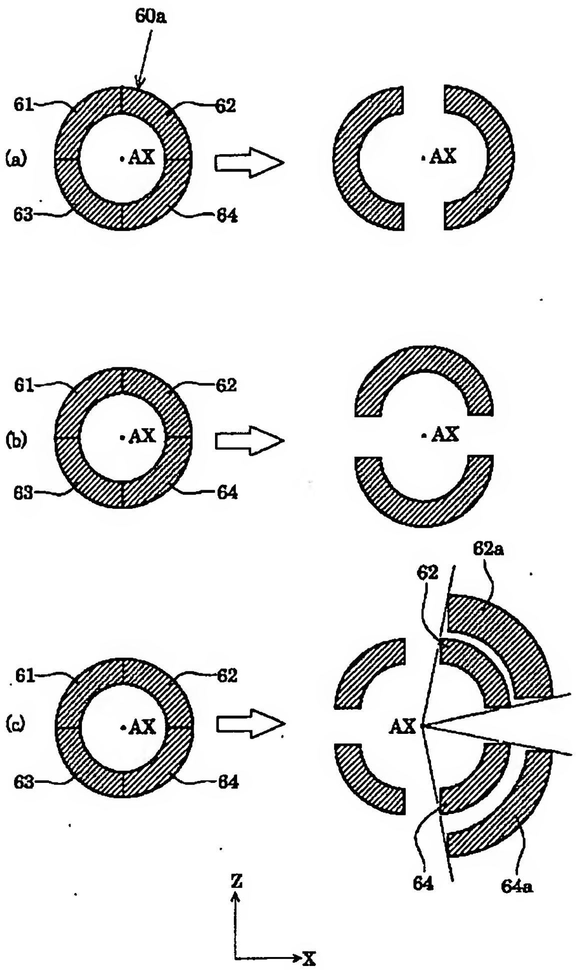


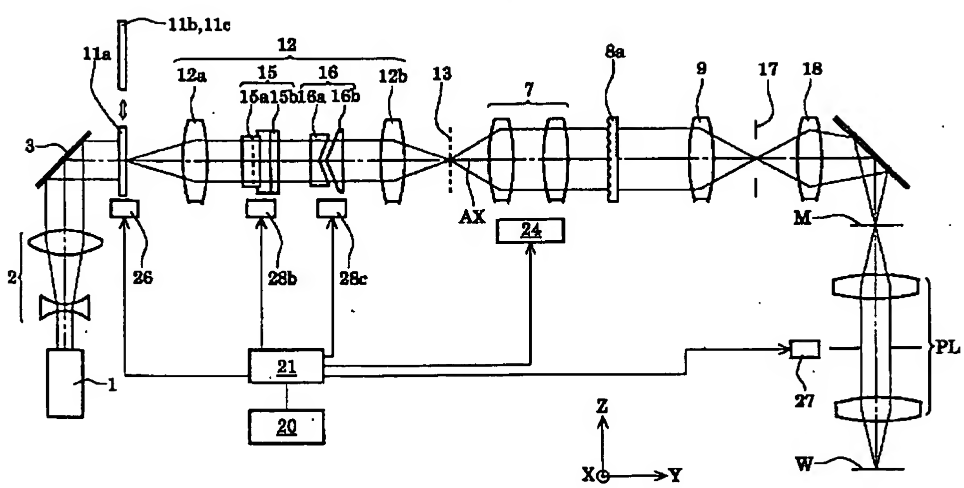
[Drawing 24]



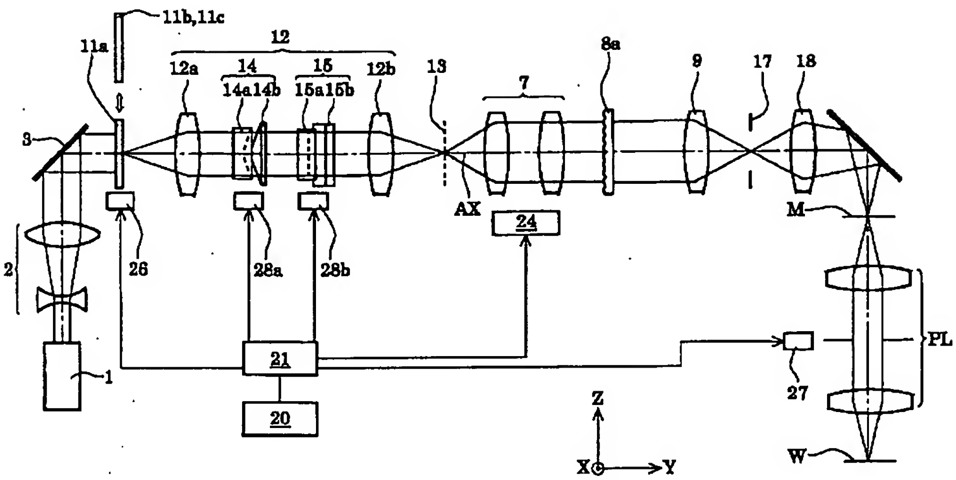
[Drawing 22]



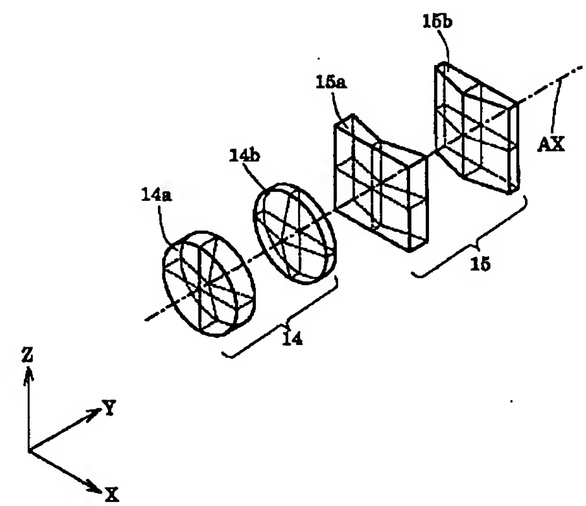
[Drawing 25]



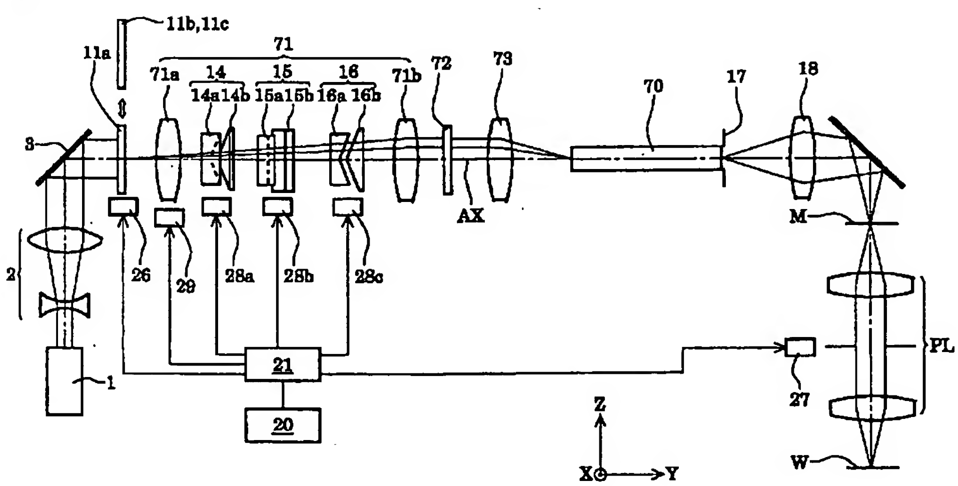
[Drawing 27]



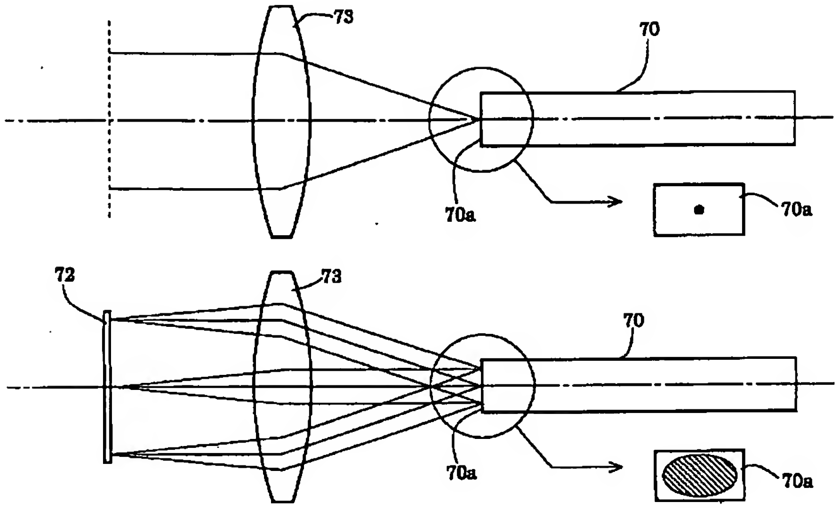
[Drawing 28]



[Drawing 29]



[Drawing 30]



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette]Printing of amendment by regulation of Patent Law Article 17 of 2
[Section Type] The 2nd Type of the part VII gate
[Publication date]Heisei 20(2008) April 24 (2008.4.24)

[Publication No.]JP,2002-231619,A (P2002-231619A)
[Date of Publication]Heisei 14(2002) August 16 (2002.8.16)
[Application number]Application for patent 2001-74240 (P2001-74240)
[International Patent Classification]

H01L 21/027 (2006.01)

G02B 3/00 (2006.01)

G02B 5/04 (2006.01)

G02B 19/00 (2006.01

G03F 7/20 (2006.01)
[FI]

H01L 21/30 515 D

G02B 3/00 A

G02B 5/04 F

G02B 19/00

G03F 7/20 521
[Written Amendment]
[Filing date]Heisei 20(2008) March 11 (2008.3.11)
[Amendment 1]
[Document to be Amended]Description
[Item(s) to be Amended]Claims
[Method of Amendment]Change
[The contents of amendment]
[Claim(s)]
[Claim 1]In an illumination optical device provided with a light guide optical system for leading light flux from an optical integrator and this optical integrator for forming many light sources based on light flux from a light source means to an irradiated plane,
A light flux sensing element for changing into light flux which has light flux which has predetermined sectional shape for light flux from said light source means, or predetermined light intensity distribution,
It is arranged in an optical path between said light flux sensing element and said optical integrator, An illumination optical device provided with an aspect ratio change element which changes an aspect ratio of said incoming beam in order to change the degree of incidence angle along a prescribed direction of an incoming beam to said optical integrator.
[Claim 2]The illumination optical device according to claim 1, wherein said aspect ratio change element is constituted pivotable considering an optic axis as a center.
[Claim 3]The 1st aspect ratio change element for said aspect ratio change element to change the degree of incidence angle which met in the 1st direction of an incoming beam to said optical integrator, The illumination optical device according to claim 1 having the 2nd aspect ratio change element for changing the degree of incidence angle which met in said 1st direction of an incoming beam to said optical integrator, and the 2nd direction that intersects perpendicularly.
[Claim 4]The 1st prism with which said aspect ratio change element has a refracting interface of a concave section along said prescribed direction, It has the 2nd prism that has a refracting interface of said concave section of this 1st prism, and a refracting interface of a convex section formed complementarily, An illumination optical device given in any 1 clause of Claims 1-3, wherein either is constituted movable in accordance with an optic axis at least among said 1st prism and said 2nd prism.
[Claim 5]The illumination optical device according to claim 4, wherein said concave section of said 1st prism has V character-like form.

[Claim 6]In an illumination optical device provided with an illumination-light study system which illuminates an object to be illuminated,

Said illumination-light study system is provided with a variable means which makes variable either [at least] a size of illumination light in a pupil of this illumination-light study system, or the form,
The 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction to which an optic axis of said illumination-light study system and said variable means cross at right angles,
The 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction,
An illumination optical device having a variable power optical system which makes a size of said illumination light variable.
[Claim 7]The illumination optical device according to claim 6, wherein said illumination-light study system is provided with an optical form conversion method which leads illumination light which changed into light flux form of a request of form of said illumination light, and was changed into light flux form of this request to said variable means.
[Claim 8]The illumination optical device comprising according to claim 7:
The 1st diffracted-light study component from which said optical form conversion method changes form of said illumination light into the 1st light flux form.
The 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes form of said illumination light into the 2nd light flux form.

[Claim 9]An illumination optical device given in any 1 clause of Claims 6-8, wherein said illumination-light study system is provided with an optical integrator which is arranged in an optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[Claim 10]In an illumination optical device provided with an illumination-light study system which illuminates an object to be illuminated,
Said illumination-light study system is provided with a variable means which makes variable either [at least] a size of illumination light in a pupil of this illumination-light study system, or the form,
An illumination optical device comprising:
A zona-orbicularis ratio variable means which gives an operation changed in the shape of [in which said variable means has a zona-orbicularis ratio of a request of said illumination light] zona orbicularis.
The 1st displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system.

[Claim 11]The illumination optical device according to claim 10, wherein said variable means has a variable power optical system which makes a size of said illumination light variable.
[Claim 12]The illumination optical device according to claim 10 or 11 having the 2nd displacement means that displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that said optic axis and said variable means cross at right angles, and intersects said 1st direction.
[Claim 13]An illumination optical device given in any 1 clause of Claims 10-12, wherein said illumination-light study system is provided with an optical form conversion method which leads illumination light which changed into light flux form of a request of form of said illumination light, and was changed into light flux form of this request to said variable means.
[Claim 14]The illumination optical device comprising according to claim 13:
The 1st diffracted-light study component from which said optical form conversion method changes form of said illumination light into the 1st light flux form.
The 2nd diffracted-light study component which is provided exchangeable with this 1st diffracted-light study component, and changes form of said illumination light into the 2nd light flux form.

[Claim 15]An illumination optical device given in any 1 clause of Claims 10-14, wherein said illumination-light study system is provided with an optical integrator which is arranged in an optical path between said variable means and said object to be illuminated, and illuminates said object to be illuminated uniformly.
[Claim 16]An exposure device comprising:
An illumination optical device given in any 1 clause of Claims 1-15.
A projection optical system for carrying out projection exposure of the pattern of a mask arranged in said irradiated plane to a photosensitive substrate.

[Claim 17]A manufacturing method of a micro device characterized by comprising the following.
An exposure process which exposes a pattern of said mask on said photosensitive substrate with the exposure device according to claim 16.
A developing process which develops said photosensitive substrate exposed by said exposure process.

[Claim 18]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
The 1st displacement process which displaces illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction to which an optic axis of said illumination-light study system and said Lighting Sub-Division process cross at right angles in a pupil of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction, and a variable power process of making a size of said illumination light variable.

[Claim 19]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
A zona-orbicularis operation grant process that said Lighting Sub-Division process gives an operation which changes illumination light in a pupil of said illumination-light study system in the shape of zona orbicularis, The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
[Claim 20]The exposure method according to claim 19, wherein said Lighting Sub-Division process includes further a variable power process of making a size of said illumination light variable.
[Claim 21]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
Said Lighting Sub-Division process includes a change process of changing Lighting Sub-Division conditions over said mask,
Said change process includes a selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system,
A zona-orbicularis operation grant process that said 1st setting-out process gives an operation which changes illumination light in a pupil of said illumination-light study system in the shape of zona orbicularis, It intersects perpendicularly with the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, and said optic axis, and said 1st direction and the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd crossing direction are included,
An exposure method comprising:
The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction to which an optic axis of said illumination-light study system and said 2nd setting-out process cross at right angles.
The 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
A variable power process of making a size of said illumination light variable.

[Claim 22]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
Said Lighting Sub-Division process includes a variable process of making variable either [at least] a size of illumination light in a pupil of said illumination-light study system, or the form,
An exposure method comprising:
zona orbicularis which gives an operation changed in the shape of [in which the aforementioned variable process has a zona-orbicularis ratio of a request of said illumination light] zona orbicularis -- a ratio -- a variable process.
The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system.

[Claim 23]The exposure method according to claim 22, wherein the aforementioned variable process includes further a variable power process of making a size of said illumination light variable.
[Claim 24]The exposure method according to claim 22 or 23, wherein the aforementioned variable process includes further the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
[Claim 25]An exposure method given in any 1 clause of Claims 22-24, wherein said Lighting Sub-Division process includes further an optical form converting process which changes form of said illumination light into desired light flux form in front of the aforementioned variable process.
[Claim 26]The 1st diffraction process from which said optical form converting process changes form of said illumination light into the 1st light flux form using the 1st diffracted-light study component, The exposure method according to claim 25 including the 2nd diffraction process of changing form of said illumination light into the 2nd light flux form using said 1st diffracted-light study component and the 2nd diffracted-light study component provided exchangeable.
[Claim 27]An exposure method given in any 1 clause of Claims 22-26, wherein said Lighting Sub-Division process includes a uniform illumination process of using an optical integrator and illuminating said object to be illuminated uniformly after the aforementioned variable process.
[Claim 28]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
Said Lighting Sub-Division process includes a change process of changing Lighting Sub-Division conditions over said mask,
Said change process includes a selection process which chooses at least one side of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, and the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system,
zona orbicularis which gives an operation changed in the shape of [in which said 1st setting-out process has a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis -- a ratio -- including a variable process and a variable power process of making a size of said illumination light variable

An exposure method, wherein said 2nd setting-out process includes a displacement process which displaces said illumination light symmetrically on both sides of said optic axis along a prescribed direction which intersects perpendicularly with an optic axis of said illumination-light study system, and a variable power process of making a size of said illumination light variable.
[Claim 29]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
zona orbicularis which gives an operation changed in the shape of [in which said Lighting Sub-Division process has a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis -- a ratio -- with a variable process. The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, An exposure method including the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
[Claim 30]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate is included,
Said Lighting Sub-Division process includes a change process of changing Lighting Sub-Division conditions over said mask,
Said change process includes a selection process which chooses at least one of the 1st setting-out process of setting up the 1st Lighting Sub-Division conditions of said illumination-light study system, the 2nd setting-out process of setting up the 2nd Lighting Sub-Division conditions of said illumination-light study system, and the 3rd setting-out processes of setting up the 3rd Lighting Sub-Division conditions of said illumination-light study system,
zona orbicularis which gives an operation changed in the shape of [in which said 1st setting-out process has a zona-orbicularis ratio of a request of illumination light in a pupil of said illumination-light study system] zona orbicularis -- a ratio -- with a variable process. It intersects perpendicularly with the 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction that intersects perpendicularly with an optic axis of said illumination-light study system, and said optic axis, and said 1st direction and the 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd crossing direction are included,
zona orbicularis which gives an operation changed in the shape of [in which said 2nd setting-out process has a zona-orbicularis ratio of a request of said illumination light] zona orbicularis -- a ratio -- including a variable process and a variable power process of making a size of said illumination light variable
An exposure method comprising:
The 1st displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 1st direction to which an optic axis of said illumination-light study system and said 3rd setting-out process cross at right angles.
The 2nd displacement process which displaces said illumination light symmetrically on both sides of said optic axis in accordance with the 2nd direction that intersects perpendicularly with said optic axis, and intersects said 1st direction.
A variable power process of making a size of said illumination light variable.

[Claim 31]An exposure process which exposes a pattern of said mask to said photosensitive substrate using an exposure method given in any 1 clause of Claims 18-30,
A manufacturing method of a micro device including a developing process which develops said photosensitive substrate exposed by said exposure process.
[Claim 32]In an exposure method which exposes a pattern of a mask to a photosensitive substrate,
The Lighting Sub-Division process of illuminating said mask via an illumination-light study system,
A projection process of projecting a pattern image of said mask on said photosensitive substrate using a projection optical system,
A measurement step which measures the optical property of said projection optical system is included,
An exposing condition setting-out process of setting a sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95 when said Lighting Sub-Division process performing said projection process,
An exposure method including a measurement condition setting-out process of setting a sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 when performing said measurement step.
[Claim 33]A scanning process to which said mask and said photosensitive substrate are moved along a scanning direction is further included when performing said projection process,
Said Lighting Sub-Division process includes a process of forming an illuminated field of rectangular shape which has a longitudinal direction and the transverse direction on said mask,
The exposure method according to claim 32 characterized by filling a relation of 0.05<Ls/Ll<0.7 when setting the length Ls of the transverse direction of said illuminated field, and the length of a longitudinal direction of said illuminated field to Ll.
[Claim 34]In an exposure device which exposes a pattern of a mask to a photosensitive substrate,
An illumination-light study system which illuminates said mask,
It has a projection optical system which projects a pattern image of said mask on said photosensitive substrate,
When said illumination-light study system exposes a pattern of said mask to said photosensitive substrate, it sets a sigma value as Lighting Sub-Division conditions as the range of 0.4<=sigma<=0.95, and. An exposure device having a Lighting Sub-Division conditioning means to set a sigma value as Lighting Sub-Division conditions as the range of 0.01<=sigma<=0.3 when [in which the optical property of said projection optical system is measured] measuring.
[Claim 35]When exposing a pattern of said mask to said photosensitive substrate, it has further a scanning means to which said mask and said photosensitive substrate are moved along a scanning direction,
When setting to Ll the length of a longitudinal direction of said illuminated field which sets to Ls the length of the transverse direction of said illuminated field formed in said mask of said illumination-light study system, and is formed in said mask of said illumination-light study system, The exposure device according to claim 34 filling a relation of 0.05<Ls/Ll<0.7.

[Translation done.]

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審査請求　未請求　請求項の数38　ＯＬ　（全 35 頁）

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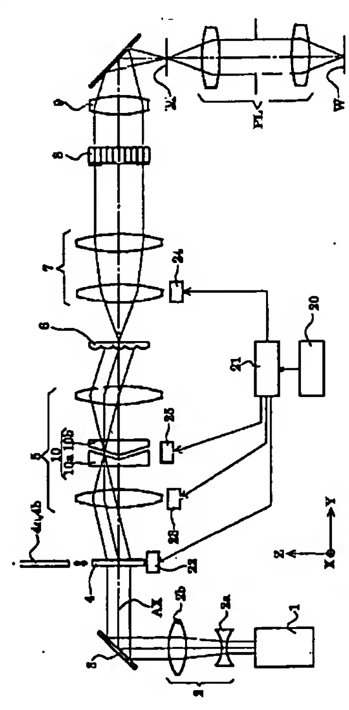
(54)【発明の名称】　照明光学装置および該照明光学装置を備えた露光装置

(57)【要約】
【課題】　被照射面上の直交する二方向で互いに異なる照明条件を実現することのできる照明光学装置。
【解決手段】　光源手段（１）からの光束に基づいて第１多数光源を形成するための第１オプティカルインテグレータ（６）と、第１多数光源からの光束に基づいてより多数の第２多数光源を形成するための第２オプティカルインテグレータ（８）との間の光路中に、第２多数光源の全体の大きさを相似的に変更するための変倍光学系（７）が配置されている。また、第１オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるための入射光束の縦横比を変更する縦横比変更素子（１０）を備えている。



【特許請求の範囲】
【請求項１】　光源手段からの光束に基づいて第１多数光源を形成するための第１オプティカルインテグレータと、前記第１多数光源からの光束に基づいてより多数の第２多数光源を形成するための第２オプティカルインテグレータとを備え、前記第２多数光源からの光束で被照射面を照明する照明光学装置において、
前記第１オプティカルインテグレータと前記第２オプティカルインテグレータとの間の光路中に配置されて、前記第２多数光源の全体の大きさを相似的に変更するための変倍光学系と、
前記第１オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるために前記入射光束の縦横比を変更する縦横比変更素子とを備えていることを特徴とする照明光学装置。
【請求項２】　光源手段からの光束に基づいて多数光源を形成するためのオプティカルインテグレータと、該オプティカルインテグレータからの光束を被照射面へ導くための導光光学系とを備えた照明光学装置において、
前記光源手段からの光束を所定の断面形状を有する光束または所定の光強度分布を有する光束に変換するための光束変換素子と、
前記光束変換素子と前記オプティカルインテグレータとの間の光路中に配置されて、前記オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるために前記入射光束の縦横比を変更する縦横比変更素子とを備えていることを特徴とする照明光学装置。
【請求項３】　前記縦横比変更素子は、光軸を中心として回転可能に構成されていることを特徴とする請求項１または２に記載の照明光学装置。
【請求項４】　前記縦横比変更素子は、前記オプティカルインテグレータまたは前記第１オプティカルインテグレータへの入射光束の第１方向に沿った入射角度を変化させるための第１縦横比変更素子と、前記オプティカルインテグレータまたは前記第１オプティカルインテグレータへの入射光束の前記第１方向と直交する第２方向に沿った入射角度を変化させるための第２縦横比変更素子とを有することを特徴とする請求項１または２に記載の照明光学装置。
【請求項５】　前記縦横比変更素子は、前記所定方向に沿って凹状断面の屈折面を有する第１プリズムと、該第１プリズムの前記凹状断面の屈折面と相補的に形成された凸状断面の屈折面を有する第２プリズムとを有し、前記第１プリズムおよび前記第２プリズムのうち少なくともいずれか一方が光軸に沿って移動可能に構成されていることを特徴とする請求項１乃至４のいずれか１項に記載の照明光学装置。
【請求項６】　前記第１プリズムの前記凹状断面は、Ｖ字状の形状を有することを特徴とする請求項５に記載の照明光学装置。
【請求項７】　請求項１乃至６のいずれか１項に記載の照明光学装置と、前記被照射面に配置されたマスクのパターンを感光性基板に投影露光するための投影光学系とを備えていることを特徴とする露光装置。
【請求項８】　請求項７に記載の露光装置により前記マスクのパターンを前記感光性基板上に露光する露光工程と、前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法。
【請求項９】　被照明物体を照明する照明光学系を備えた照明光学装置において、
前記照明光学系は、該照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変手段を備え、
前記可変手段は、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位手段と、
前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位手段と、
前記照明光の大きさを可変とする変倍光学系とを有することを特徴とする照明光学装置。
【請求項１０】　前記照明光学系は、前記照明光の形状を所望の光束形状に変換し、該所望の光束形状に変換された照明光を前記可変手段へ導く光形状変換手段を備えていることを特徴とする請求項９に記載の照明光学装置。
【請求項１１】　前記光形状変換手段は、前記照明光の形状を第１の光束形状に変換する第１回折光学部材と、該第１回折光学部材と交換可能に設けられて前記照明光の形状を第２の光束形状に変換する第２回折光学部材とを有することを特徴とする請求項１０に記載の照明光学装置。
【請求項１２】　前記照明光学系は、前記可変手段と前記被照明物体との間の光路中に配置されて前記被照明物体を均一に照明するオプティカルインテグレータを備えていることを特徴とする請求項９乃至１１のいずれか１項に記載の照明光学装置。
【請求項１３】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記照明光学系の瞳での照明光を輪帯状に変換する作用を付与する輪帯作用付与工程と、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程とを含むことを特徴とする露光方

法。

【請求項14】　前記照明工程は、前記照明光の大きさを可変とする変倍工程をさらに含むことを特徴とする請求項13に記載の露光方法。

【請求項15】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記照明光学系の瞳において前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法。

【請求項16】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、
前記変更工程は、前記照明光学系の第1照明条件を設定する第1設定工程と、前記照明光学系の第2照明条件を設定する第2設定工程との少なくとも一方を選択する選択工程を含み、
前記第1設定工程は、前記照明光学系の瞳での照明光を輪帯状に変換する作用を付与する輪帯作用付与工程と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程とを含み、
前記第2設定工程は、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法。

【請求項17】　被照明物体を照明する照明光学系を備えた照明光学装置において、
前記照明光学系は、該照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変手段を備え、
前記可変手段は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変手段と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位手段とを有することを特徴とする照明光学装置。

【請求項18】　前記可変手段は、前記照明光の大きさを可変とする変倍光学系を有することを特徴とする請求項17に記載の照明光学装置。

【請求項19】　前記可変手段は、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位手段を有することを特徴とする請求項17または18に記載の照明光学装置。

【請求項20】　前記照明光学系は、前記照明光の形状を所望の光束形状に変換し、該所望の光束形状に変換された照明光を前記可変手段へ導く光形状変換手段を備えていることを特徴とする請求項17乃至19のいずれか1項に記載の照明光学装置。

【請求項21】　前記光形状変換手段は、前記照明光の形状を第1の光束形状に変換する第1回折光学部材と、該第1回折光学部材と交換可能に設けられて前記照明光の形状を第2の光束形状に変換する第2回折光学部材とを有することを特徴とする請求項20に記載の照明光学装置。

【請求項22】　前記照明光学系は、前記可変手段と前記被照明物体との間の光路中に配置されて前記被照明物体を均一に照明するオプティカルインテグレータを備えていることを特徴とする請求項17乃至21のいずれか1項に記載の照明光学装置。

【請求項23】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変工程を含み、
前記可変工程は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程とを含むことを特徴とする露光方法。

【請求項24】　前記可変工程は、前記照明光の大きさを可変とする変倍工程をさらに含むことを特徴とする請求項23に記載の露光方法。

【請求項25】　前記可変工程は、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程をさらに含むことを特徴とする請求項23または24に記載の露光方法。

【請求項26】　前記照明工程は、前記可変工程の前に、前記照明光の形状を所望の光束形状に変換する光形状変換工程をさらに含むことを特徴とする請求項23乃至25のいずれか1項に記載の露光方法。

【請求項２７】　前記光形状変換工程は、第１回折光学部材を用いて前記照明光の形状を第１の光束形状に変換する第１回折工程と、前記第１回折光学部材と交換可能に設けられた第２回折光学部材を用いて前記照明光の形状を第２の光束形状に変換する第２回折工程とを含むことを特徴とする請求項２６に記載の露光方法。

【請求項２８】　前記照明工程は、前記可変工程の後に、オプティカルインテグレータを用いて前記被照明物体を均一に照明する均一照明工程を含むことを特徴とする請求項２３乃至２７のいずれか１項に記載の露光方法。

【請求項２９】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、
前記変更工程は、前記照明光学系の第１照明条件を設定する第１設定工程と、前記照明光学系の第２照明条件を設定する第２設定工程との少なくとも一方を選択する選択工程を含み、
前記第１設定工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光の大きさを可変とする変倍工程とを含み、
前記第２設定工程は、前記照明光学系の光軸と直交する所定方向に沿って前記光軸を挟んで対称に前記照明光を変位させる変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法。

【請求項３０】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程とを含むことを特徴とする露光方法。

【請求項３１】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、
前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、
前記変更工程は、前記照明光学系の第１照明条件を設定する第１設定工程、前記照明光学系の第２照明条件を設定する第２設定工程、および前記照明光学系の第３照明条件を設定する第３設定工程のうちの少なくとも１つを選択する選択工程を含み、
前記第１設定工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程とを含み、
前記第２設定工程は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光の大きさを可変とする変倍工程とを含み、
前記第３設定工程は、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法。

【請求項３２】　前記被照明物体としてのマスクを照明するための請求項９乃至１２および請求項１７乃至２２のいずれか１項に記載の照明光学装置と、
前記マスクのパターン像を感光性基板に投影するための投影光学系とを備えていることを特徴とする露光装置。

【請求項３３】　請求項３２に記載の露光装置を用いて前記マスクのパターンを前記感光性基板に露光する露光工程と、
前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法。

【請求項３４】　請求項１３乃至１６および請求項２３乃至３１のいずれか１項に記載の露光方法を用いて前記マスクのパターンを前記感光性基板に露光する露光工程と、
前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法。

【請求項３５】　マスクのパターンを感光性基板に露光する露光方法において、
照明光学系を介して前記マスクを照明する照明工程と、
投影光学系を用いて前記マスクのパターン像を前記感光性基板に投影する投影工程と、
前記投影光学系の光学特性を計測する計測工程とを含み、
前記照明工程は、前記投影工程を実行するのに際して照明条件としてのσ値を０．４≦σ≦０．９５の範囲に設定する露光条件設定工程と、

前記計測工程を実行するのに際して照明条件としてのσ値を０．０１≦σ≦０．３の範囲に設定する計測条件設定工程とを含むことを特徴とする露光方法。

【請求項３６】　前記投影工程を実行するのに際して、前記マスクと前記感光性基板とを走査方向に沿って移動させる走査工程をさらに含み、

前記照明工程は、長手方向と短手方向とを有する矩形状の照明領域を前記マスク上に形成する工程を含み、

前記照明領域の短手方向の長さＬｓ、前記照明領域の長手方向の長さをＬｌとするとき、０．０５＜Ｌｓ／Ｌｌ＜０．７の関係を満たすことを特徴とする請求項３５に記載の露光方法。

【請求項３７】　マスクのパターンを感光性基板に露光する露光装置において、

前記マスクを照明する照明光学系と、

前記マスクのパターン像を前記感光性基板に投影する投影光学系とを備え、

前記照明光学系は、前記マスクのパターンを前記感光性基板に露光する際に、照明条件としてのσ値を０．４≦σ≦０．９５の範囲に設定すると共に、前記投影光学系の光学特性を計測する計測する際に、照明条件としてのσ値を０．０１≦σ≦０．３の範囲に設定する照明条件設定手段を有することを特徴とする露光装置。

【請求項３８】　前記マスクのパターンを前記感光性基板に露光する際に、前記マスクと前記感光性基板とを走査方向に沿って移動させる走査手段をさらに備え、

前記照明光学系により前記マスクに形成される前記照明領域の短手方向の長さをＬｓとし、前記照明光学系により前記マスクに形成される前記照明領域の長手方向の長さをＬｌとするとき、０．０５＜Ｌｓ／Ｌｌ＜０．７の関係を満たすことを特徴とする請求項３７に記載の露光装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は照明光学装置および該照明光学装置を備えた露光装置に関し、特に半導体素子、撮像素子、液晶表示素子、薄膜磁気ヘッド等のマイクロデバイスをリソグラフィー工程で製造するための露光装置に好適な照明光学装置に関する。

【０００２】

【従来の技術】この種の典型的な露光装置においては、光源から射出された光束が、オプティカルインテグレータとしてのフライアイレンズを介して、多数の光源からなる実質的な面光源としての二次光源を形成する。二次光源からの光束は、フライアイレンズの後側焦点面の近傍に配置された開口絞りを介して制限された後、コンデンサーレンズに入射する。

【０００３】コンデンサーレンズにより集光された光束は、所定のパターンが形成されたマスクを重畳的に照明する。マスクのパターンを透過した光は、投影光学系を介してウェハ上に結像する。こうして、ウェハ上には、マスクパターンが投影露光（転写）される。なお、マスクに形成されたパターンは高集積化されており、この微細パターンをウェハ上に正確に転写するにはウェハ上において均一な照度分布を得ることが不可欠である。

【０００４】

【発明が解決しようとする課題】そこで、フライアイレンズの後側焦点面に円形状の二次光源を形成し、その大きさを変化させて照明のコヒーレンシィσ（σ値＝開口絞り径／投影光学系の瞳径、あるいはσ値＝照明光学系の射出側開口数／投影光学系の入射側開口数）を変化させる技術が注目されている。また、フライアイレンズの後側焦点面に輪帯状や４極状の二次光源を形成し、投影光学系の焦点深度や解像力を向上させる技術が注目されている。

【０００５】しかしながら、上述のような従来技術では、円形状の二次光源に基づく通常の円形照明の場合も、輪帯状や４極状の二次光源に基づく変形照明（輪帯照明や４極照明）の場合も、被照射面であるマスク上の一点に入射する光束の断面形状がマスク上の直交する二方向に関して同じ位置関係にある。換言すると、従来技術では、被照射面上の直交する二方向で照明条件が同じである。その結果、マスクパターンに方向性がある場合、マスク上の直交する二方向で最適な照明条件を実現することができない。ところで、また、近年においては、適切な照明条件のもとでマスクのパターンを正確に転写することと、同時に、マスクのパターンを正確に転写するのに際して、投影光学系の光学性能を高精度で確認し得ることが切望されている。

【０００６】本発明は、前述の課題に鑑みてなされたものであり、被照射面上の直交する二方向で互いに異なる照明条件を実現することのできる、照明光学装置および該照明光学装置を備えた露光装置を提供することを目的とする。また、本発明は、パターンに方向性があるマスク上の直交する二方向で最適な照明条件を設定することのできる露光装置を用いて、良好な照明条件のもとで良好なマイクロデバイスを製造することのできるマイクロデバイスの製造方法を提供することを目的とする。さらに、また、本発明は、適切な照明条件のもとでマスクのパターンを正確に転写することができ、同時に、マスクのパターンを正確に転写するのに際して、投影光学系の光学性能を高精度で確認し得る露光装置や露光方法等を提供することも目的とする。

【０００７】

【課題を解決するための手段】前記課題を解決するために、本発明の第１発明では、光源手段からの光束に基づいて第１多数光源を形成するための第１オプティカルインテグレータと、前記第１多数光源からの光束に基づいてより多数の第２多数光源を形成するための第２オプティカルインテグレータとを備え、前記第２多数光源から

の光束で被照射面を照明する照明光学装置において、前記第1オプティカルインテグレータと前記第2オプティカルインテグレータとの間の光路中に配置されて、前記第2多数光源の全体の大きさを相似的に変更するための変倍光学系と、前記第1オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるために前記入射光束の縦横比を変更する縦横比変更素子とを備えていることを特徴とする照明光学装置を提供する。

【0008】本発明の第2発明では、光源手段からの光束に基づいて多数光源を形成するためのオプティカルインテグレータと、該オプティカルインテグレータからの光束を被照射面へ導くための導光光学系とを備えた照明光学装置において、前記光源手段からの光束を所定の断面形状を有する光束または所定の光強度分布を有する光束に変換するための光束変換素子と、前記光束変換素子と前記オプティカルインテグレータとの間の光路中に配置されて、前記オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるために前記入射光束の縦横比を変更する縦横比変更素子とを備えていることを特徴とする照明光学装置を提供する。

【0009】第1発明または第2発明の好ましい態様によれば、前記縦横比変更素子は、光軸を中心として回転可能に構成されている。あるいは、前記縦横比変更素子は、前記オプティカルインテグレータまたは前記第1オプティカルインテグレータへの入射光束の第1方向に沿った入射角度を変化させるための第1縦横比変更素子と、前記オプティカルインテグレータまたは前記第1オプティカルインテグレータへの入射光束の前記第1方向と直交する第2方向に沿った入射角度を変化させるための第2縦横比変更素子とを有することが好ましい。

【0010】また、第1発明の好ましい態様によれば、前記縦横比変更素子は、前記所定方向に沿って凹状断面の屈折面を有する第1プリズムと、該第1プリズムの前記凹状断面の屈折面と相補的に形成された凸状断面の屈折面を有する第2プリズムとを有し、前記第1プリズムおよび前記第2プリズムのうち少なくともいずれか一方が光軸に沿って移動可能に構成されている。この場合、前記第1プリズムの前記凹状断面は、V字状の形状を有することが好ましい。

【0011】本発明の第3発明では、第1発明または第2発明の照明光学装置と、前記被照射面に配置されたマスクのパターンを感光性基板に投影露光するための投影光学系とを備えていることを特徴とする露光装置を提供する。

【0012】本発明の第4発明では、第3発明の露光装置により前記マスクのパターンを前記感光性基板上に露光する露光工程と、前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法を提供する。

【0013】本発明の第5発明では、被照明物体を照明する照明光学系を備えた照明光学装置において、前記照明光学系は、該照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変手段を備え、前記可変手段は、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位手段と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位手段と、前記照明光の大きさを可変とする変倍光学系とを有することを特徴とする照明光学装置を提供する。

【0014】第5発明の好ましい態様によれば、前記照明光学系は、前記照明光の形状を所望の光束形状に変換し、該所望の光束形状に変換された照明光を前記可変手段へ導く光形状変換手段を備えている。この場合、前記光形状変換手段は、前記照明光の形状を第1の光束形状に変換する第1回折光学部材と、該第1回折光学部材と交換可能に設けられて前記照明光の形状を第2の光束形状に変換する第2回折光学部材とを有することが好ましい。また、前記照明光学系は、前記可変手段と前記被照明物体との間の光路中に配置されて前記被照明物体を均一に照明するオプティカルインテグレータを備えていることが好ましい。

【0015】本発明の第6発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記照明光学系の瞳での照明光を輪帯状に変換する作用を付与する輪帯作用付与工程と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程とを含むことを特徴とする露光方法を提供する。この場合、前記照明工程は、前記照明光の大きさを可変とする変倍工程をさらに含むことが好ましい。

【0016】本発明の第7発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記照明光学系の瞳において前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法を提供する。

【0017】本発明の第8発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系

を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、前記変更工程は、前記照明光学系の第1照明条件を設定する第1設定工程と、前記照明光学系の第2照明条件を設定する第2設定工程との少なくとも一方を選択する選択工程を含み、前記第1設定工程は、前記照明光学系の瞳での照明光を輪帯状に変換する作用を付与する輪帯作用付与工程と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程とを含み、前記第2設定工程は、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程と、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法を提供する。

【0018】本発明の第9発明では、被照明物体を照明する照明光学系を備えた照明光学装置において、前記照明光学系は、該照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変手段を備え、前記可変手段は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変手段と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位手段とを有することを特徴とする照明光学装置を提供する。

【0019】第9発明の好ましい態様によれば、前記可変手段は、前記照明光の大きさを可変とする変倍光学系を有する。また、前記可変手段は、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位手段を有することが好ましい。さらに、前記照明光学系は、前記照明光の形状を所望の光束形状に変換し、該所望の光束形状に変換された照明光を前記可変手段へ導く光形状変換手段を備えていることが好ましい。この場合、前記光形状変換手段は、前記照明光の形状を第1の光束形状に変換する第1回折光学部材と、該第1回折光学部材と交換可能に設けられて前記照明光の形状を第2の光束形状に変換する第2回折光学部材とを有することが好ましい。また、前記照明光学系は、前記可変手段と前記被照明物体との間の光路中に配置されて前記被照明物体を均一に照明するオプティカルインテグレータを備えていることが好ましい。

【0020】本発明の第10発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記照明光学系の瞳での照明光の大きさおよび形状のうちの少なくとも一方を可変とする可変工程を含み、前記可変工程は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する第1方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第1変位工程とを含むことを特徴とする露光方法を提供する。

【0021】第10発明の好ましい態様によれば、前記可変工程は、前記照明光の大きさを可変とする変倍工程をさらに含む。また、前記可変工程は、前記光軸と直交し且つ前記第1方向と交差する第2方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第2変位工程をさらに含むことが好ましい。さらに、前記照明工程は、前記可変工程の前に、前記照明光の形状を所望の光束形状に変換する光形状変換工程をさらに含むことが好ましい。この場合、前記光形状変換工程は、第1回折光学部材を用いて前記照明光の形状を第1の光束形状に変換する第1回折工程と、前記第1回折光学部材と交換可能に設けられた第2回折光学部材を用いて前記照明光の形状を第2の光束形状に変換する第2回折工程とを含むことが好ましい。また、前記照明工程は、前記可変工程の後に、オプティカルインテグレータを用いて前記被照明物体を均一に照明する均一照明工程を含むことが好ましい。

【0022】本発明の第11発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、前記変更工程は、前記照明光学系の第1照明条件を設定する第1設定工程と、前記照明光学系の第2照明条件を設定する第2設定工程との少なくとも一方を選択する選択工程を含み、前記第1設定工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光の大きさを可変とする変倍工程とを含み、前記第2設定工程は、前記照明光学系の光軸と直交する所定方向に沿って前記光軸を挟んで対称に前記照明光を変位させる変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法を提供する。

【0023】本発明の第12発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する

第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程とを含むことを特徴とする露光方法を提供する。

【００２４】本発明の第１３発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、前記マスクのパターン像を前記感光性基板に投影する投影工程とを含み、前記照明工程は、前記マスクに対する照明条件を変更する変更工程を含み、前記変更工程は、前記照明光学系の第１照明条件を設定する第１設定工程、前記照明光学系の第２照明条件を設定する第２設定工程、および前記照明光学系の第３照明条件を設定する第３設定工程のうちの少なくとも１つを選択する選択工程を含み、前記第１設定工程は、前記照明光学系の瞳での照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程とを含み、前記第２設定工程は、前記照明光を所望の輪帯比を持つ輪帯状に変換する作用を付与する輪帯比可変工程と、前記照明光の大きさを可変とする変倍工程とを含み、前記第３設定工程は、前記照明光学系の光軸と直交する第１方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第１変位工程と、前記光軸と直交し且つ前記第１方向と交差する第２方向に沿って前記光軸を挟んで対称に前記照明光を変位させる第２変位工程と、前記照明光の大きさを可変とする変倍工程とを含むことを特徴とする露光方法を提供する。

【００２５】本発明の第１４発明では、前記被照明物体としてのマスクを照明するための第５発明または第９発明に記載の照明光学装置と、前記マスクのパターン像を感光性基板に投影するための投影光学系とを備えていることを特徴とする露光装置を提供する。本発明の第１５発明では、第１４発明の露光装置を用いて前記マスクのパターンを前記感光性基板に露光する露光工程と、前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法を提供する。本発明の第１６発明では、第６発明～第８発明または第１０発明～第１３発明の露光方法を用いて前記マスクのパターンを前記感光性基板に露光する露光工程と、前記露光工程により露光された前記感光性基板を現像する現像工程とを含むことを特徴とするマイクロデバイスの製造方法を提供する。

【００２６】本発明の第１７発明では、マスクのパターンを感光性基板に露光する露光方法において、照明光学系を介して前記マスクを照明する照明工程と、投影光学系を用いて前記マスクのパターン像を前記感光性基板に投影する投影工程と、前記投影光学系の光学特性を計測する計測工程とを含み、前記照明工程は、前記投影工程を実行するのに際して照明条件としてのσ値を０．４≦σ≦０．９５の範囲に設定する露光条件設定工程と、前記計測工程を実行するのに際して照明条件としてのσ値を０．０１≦σ≦０．３の範囲に設定する計測条件設定工程とを含むことを特徴とする露光方法を提供する。この場合、前記投影工程を実行するのに際して、前記マスクと前記感光性基板とを走査方向に沿って移動させる走査工程をさらに含み、前記照明工程は、長手方向と短手方向とを有する矩形状の照明領域を前記マスク上に形成する工程を含み、前記照明領域の短手方向の長さＬｓ、前記照明領域の長手方向の長さをＬｌとするとき、０．０５＜Ｌｓ／Ｌｌ＜０．７の関係を満たすことが好ましい。

【００２７】本発明の第１８発明では、マスクのパターンを感光性基板に露光する露光装置において、前記マスクを照明する照明光学系と、前記マスクのパターン像を前記感光性基板に投影する投影光学系とを備え、前記照明光学系は、前記マスクのパターンを前記感光性基板に露光する際に、照明条件としてのσ値を０．４≦σ≦０．９５の範囲に設定すると共に、前記投影光学系の光学特性を計測する計測する際に、照明条件としてのσ値を０．０１≦σ≦０．３の範囲に設定する照明条件設定手段を有することを特徴とする露光装置を提供する。この場合、前記マスクのパターンを前記感光性基板に露光する際に、前記マスクと前記感光性基板とを走査方向に沿って移動させる走査手段をさらに備え、前記照明光学系により前記マスクに形成される前記照明領域の短手方向の長さをＬｓとし、前記照明光学系により前記マスクに形成される前記照明領域の長手方向の長さをＬｌとするとき、０．０５＜Ｌｓ／Ｌｌ＜０．７の関係を満たすことが好ましい。

【００２８】

【発明の実施の形態】本発明の典型的な実施形態においては、たとえば回折光学素子のような光束変換素子により、光源手段からの光束を４極状や輪帯状の光束に変換する。この４極状や輪帯状の光束は、所定の光学系により集光され、光軸に対して斜め方向から、マイクロフライアイレンズまたはマイクロレンズアレイ（以下、「マイクロフライアイ」という）のような第1オプティカルインテグレータへ入射する。こうして、マイクロフライアイにより第１多数光源が形成される。第１多数光源からの光束は、所定の光学系を介した後、フライアイレンズのような第2オプティカルインテグレータにより、第２多数光源すなわち４極状や輪帯状の二次光源を形成する。

【００２９】本発明では、マイクロフライアイへの入射光束の所定方向に沿った入射角度を変化させるために、

入射光束の縦横比を変更する縦横比変更素子を備えている。縦横比変更素子は、たとえば所定方向に沿ってV字状の凹状断面の屈折面を有する第1プリズムと、この第1プリズムのV字状の凹状断面の屈折面と相補的に形成されたV字状の凸状断面の屈折面を有する第2プリズムとを有する。そして、第1プリズムおよび第2プリズムのうち少なくともいずれか一方が光軸に沿って移動可能に構成されている。

【0030】したがって、第1プリズムの凹状屈折面と第2プリズムのV字状の凸状屈折面との間隔を変化させると、4極状や輪帯状の二次光源の全体の大きさが所定方向に沿って変化する。その結果、本発明の照明光学装置では、被照射面上の直交する二方向で互いに異なる照明条件を実現することができる。したがって、本発明の照明光学装置を組み込んだ露光装置では、パターンに方向性があるマスク上の直交する二方向で最適な照明条件を設定することができ、良好な照明条件のもとで良好なマイクロデバイスを製造することができる。

【0031】本発明の実施形態を、添付図面に基づいて説明する。図1は、本発明の第1実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。図1において、感光性基板であるウェハの法線方向に沿ってZ軸を、ウェハ面内において図1の紙面に平行な方向にY軸を、ウェハ面内において図1の紙面に垂直な方向にX軸をそれぞれ設定している。なお、図1では、照明光学装置が4極照明を行うように設定されている。

【0032】図1の露光装置は、露光光（照明光）を供給するための光源1として、たとえば248nm（KrF）または193nm（ArF）の波長の光を供給するエキシマレーザー光源を備えている。光源1からZ方向に沿って射出されたほぼ平行光束は、X方向に沿って細長く延びた矩形状の断面を有し、一対のレンズ2aおよび2bからなるビームエキスパンダー2に入射する。各レンズ2aおよび2bは、図1の紙面内（YZ平面内）において負の屈折力および正の屈折力をそれぞれ有する。したがって、ビームエキスパンダー2に入射した光束は、図1の紙面内において拡大され、所定の矩形状の断面を有する光束に整形される。

【0033】整形光学系としてのビームエキスパンダー2を介したほぼ平行な光束は、折り曲げミラー3でY方向に偏向された後、4極照明用の回折光学素子（DOE）4に入射する。一般に、回折光学素子は、ガラス基板に露光光（照明光）の波長程度のピッチを有する段差を形成することによって構成され、入射ビームを所望の角度に回折する作用を有する。4極照明用の回折光学素子4に入射した光束は、光軸AXを中心として等角度で特定の4つの方向に沿って回折され、4つの光束すなわち4極状の光束となる。このように、回折光学素子4は、光源1からの光束を4極状の光束に変換するための光束変換素子を構成している。

【0034】なお、回折光学素子4は、照明光路に対して挿脱自在に構成され、輪帯照明用の回折光学素子4aや通常円形照明用の回折光学素子4bと切り換え可能に構成されている。輪帯照明用の回折光学素子4aおよび通常円形照明用の回折光学素子4bの構成および作用については後述する。ここで、4極照明用の回折光学素子4と輪帯照明用の回折光学素子4aと通常円形照明用の回折光学素子4bとの間の切り換えは、制御系21からの指令に基づいて動作する第1駆動系22により行われる。

【0035】回折光学素子4を介して形成された4極状の光束は、アフォーカルズームレンズ（変倍リレー光学系）5に入射し、瞳面に4つの点像（点状の光源）を形成する。この4つの点像からの光は、ほぼ平行光束となってアフォーカルズームレンズ5から射出され、マイクロフライアイ6に入射する。なお、アフォーカルズームレンズ5は、回折光学素子4とマイクロフライアイ6の入射面とを光学的にほぼ共役な関係に維持し、且つアフォーカル系（無焦点光学系）を維持しながら、所定の範囲で倍率を連続的に変化させることができるように構成されている。ここで、アフォーカルズームレンズ5の倍率変化は、制御系21からの指令に基づいて動作する第2駆動系23により行われる。

【0036】こうして、マイクロフライアイ6の入射面には、光軸AXに対してほぼ対称に斜め方向から光束が入射する。マイクロフライアイ6は、稠密に且つ縦横に配列された多数の正六角形状の正屈折力を有する微小レンズからなる光学素子である。一般に、マイクロフライアイは、たとえば平行平面ガラス板にエッチング処理を施して微小レンズ群を形成することによって構成される。

【0037】ここで、マイクロフライアイを構成する各微小レンズは、フライアイレンズを構成する各レンズエレメントよりも微小である。また、マイクロフライアイは、互いに隔絶されたレンズエレメントからなるフライアイレンズとは異なり、多数の微小レンズが互いに隔絶されることなく一体的に形成されている。しかしながら、正屈折力を有するレンズ要素が縦横に配置されている点でマイクロフライアイはフライアイレンズと同じである。なお、図1では、図面の明瞭化のために、マイクロフライアイ6を構成する微小レンズの数を実際よりも非常に少なく表している。

【0038】したがって、マイクロフライアイ6に入射した光束は多数の微小レンズにより二次元的に分割され、各微小レンズの後側焦点面にはそれぞれ1つの4点状の光源が形成される。このように、マイクロフライアイ6は、光源1からの光束に基づいて多数の光源からなる第1多数光源を形成するための第1オプティカルインテグレータを構成している。

【0039】マイクロフライアイ6の後側焦点面に形成された多数の光源からの光束は、ズームレンズ(変倍光学系)7を介して、第2オプティカルインテグレータとしてのフライアイレンズ8を重畳的に照明する。なお、ズームレンズ7は、所定の範囲で焦点距離を連続的に変化させることのできるσ値可変用の変倍光学系であって、マイクロフライアイ6の後側焦点面とフライアイレンズ8の後側焦点面とを光学的にほぼ共役に結んでいる。換言すると、ズームレンズ7は、マイクロフライアイ6の後側焦点面とフライアイレンズ8の入射面とを実質的にフーリエ変換の関係に結んでいる。

【0040】したがって、マイクロフライアイ6の後側焦点面に形成された多数の4点状の光源からの光束は、ズームレンズ7の後側焦点面に、ひいてはフライアイレンズ8の入射面に、光軸AXに対して対称的に偏心した4つの照野からなる4極状の照野を形成する。この4極状の照野の大きさは、ズームレンズ7の焦点距離に依存して変化する。なお、ズームレンズ7の焦点距離の変化は、制御系21からの指令に基づいて動作する第3駆動系24により行われる。

【0041】フライアイレンズ8は、正の屈折力を有する多数のレンズエレメントを稠密に且つ縦横に配列することによって構成されている。なお、フライアイレンズ8を構成する各レンズエレメントは、マスク上において形成すべき照野の形状(ひいてはウェハ上において形成すべき露光領域の形状)と相似な矩形状の断面を有する。また、フライアイレンズ8を構成する各レンズエレメントの入射側の面は入射側に凸面を向けた球面状に形成され、射出側の面は射出側に凸面を向けた球面状に形成されている。したがって、フライアイレンズ8に入射した光束は多数のレンズエレメントにより二次元的に分割され、光束が入射した各レンズエレメントの後側焦点面には多数の光源がそれぞれ形成される。

【0042】こうして、図2に示すように、フライアイレンズ8の後側焦点面には、フライアイレンズ8への入射光束によって形成される照野とほぼ同じ光強度分布を有する二次光源、すなわち光軸AXに対して対称的に偏心した4つの実質的な面光源31~34からなる4極状の二次光源が形成される。このように、フライアイレンズ8は、第1オプティカルインテグレータであるマイクロフライアイ6の後側焦点面に形成された第1多数光源からの光束に基づいてより多数の光源からなる第2多数光源を形成するための第2オプティカルインテグレータを構成している。

【0043】フライアイレンズ8の後側焦点面に形成された4極状の二次光源からの光束は、必要に応じて4極状の光透過部を有する開口絞りを介して制限された後、コンデンサー光学系9の集光作用を受けた後、所定のパターンが形成されたマスクMを重畳的に照明する。マスクMのパターンを透過した光束は、投影光学系PLを介して、感光性基板であるウェハW上にマスクパターンの像を形成する。こうして、投影光学系PLの光軸AXと直交する平面(XY平面)内においてウェハWを二次元的に駆動制御しながら一括露光またはスキャン露光を行うことにより、ウェハWの各露光領域にはマスクMのパターンが逐次露光される。

【0044】なお、一括露光では、いわゆるステップ・アンド・リピート方式にしたがって、ウェハの各露光領域に対してマスクパターンを一括的に露光する。この場合、マスクM上での照明領域の形状は正方形に近い矩形状であり、フライアイレンズ8の各レンズエレメントの断面形状も正方形に近い矩形状となる。一方、スキャン露光では、いわゆるステップ・アンド・スキャン方式にしたがって、マスクおよびウェハを投影光学系に対して相対移動させながらウェハの各露光領域に対してマスクパターンをスキャン露光する。この場合、マスクM上での照明領域の形状は短辺と長辺との比がたとえば1:3の矩形状であり、フライアイレンズ8の各レンズエレメントの断面形状もこれと相似な矩形状となる。

【0045】図2を再び参照すると、フライアイレンズ8の後側焦点面に形成される4極状の二次光源は、4つの正六角形状の面光源31~34から構成されている。ここで、各面光源の中心31a~34aは光軸AXから同じ距離だけ離れており、4つの中心31a~34aを結んで形成される四角形は、光軸AXを中心としてX方向およびZ方向に平行な辺を有する正方形である。すなわち、フライアイレンズ8により形成される4極状の二次光源は、X方向およびZ方向に関して同じ位置関係にある。

【0046】したがって、被照射面であるマスクM上の任意の一点に入射する光束の断面形状も、X方向およびZ方向に関して同じ位置関係を有する4極状になる。換言すると、マスクM上の直交する二方向(X方向およびY方向)で照明条件が同じになる。そこで、第1実施形態では、マスクM上の直交する二方向で互いに異なる照明条件を実現するために、アフォーカルズームレンズ5の光路中に、一対のプリズム10aおよび10bからなるV溝アキシコン10を配置している。

【0047】図3は、アフォーカルズームレンズの光路中に配置されたV溝アキシコン系(以下、単に「V溝アキシコン」という)を構成する一対のプリズムの構成を概略的に示す図である。図1および図3に示すように、V溝アキシコン10は、光源側から順に、光源側に平面を向け且つ被照射面側に凹状の屈折面を向けた第1プリズム10aと、被照射面側に平面を向け且つ光源側に凸状の屈折面を向けた第2プリズム10bとから構成されている。第1プリズム10aの凹状屈折面10cは、X方向に平行な2つの平面から構成され、Z方向に沿ってV字状の凸状断面を有する。

【0048】第2プリズム10bの凸状屈折面10d

は、第1プリズム10aの凹状屈折面10cと互いに当接可能なように、換言すると第1プリズム10aの凹状屈折面10cと相補的に形成されている。すなわち、第2プリズム10bの凹状屈折面10dは、X方向に平行な2つの平面から構成され、Z方向に沿ってV字状の凹状断面を有する。また、第1プリズム10aおよび第2プリズム10bのうち少なくとも一方が光軸AXに沿って移動可能に構成され、凹状屈折面10cと凸状屈折面10dとの間隔が可変に構成されている。

【0049】なお、V溝アキシコン10の間隔の変化、すなわち凹状屈折面10cと凸状屈折面10dとの間隔の変化は、制御系21からの指令に基づいて動作する第4駆動系25により行われる。また、制御系21には、ステップ・アンド・リピート方式またはステップ・アンド・スキャン方式にしたがって順次露光すべき各種のマスクに関する情報などがキーボードなどの入力手段20を介して入力される。

【0050】ここで、第1プリズム10aの凹状屈折面10cと第2プリズム10bの凸状屈折面10dとが互いに当接している状態では、V溝アキシコン10は平行平面板として機能し、形成される4極状の二次光源に及ぼす影響はない。しかしながら、第1プリズム10aの凹状屈折面10cと第2プリズム10bの凸状屈折面10dとを離間させると、V溝アキシコン10はX方向に沿って平行平面板として機能するが、Z方向に沿ってビームエキスパンダーとして機能する。

【0051】したがって、凹状屈折面10cと凸状屈折面10dとの間隔の変化に伴って、マイクロフライアイ6への入射光束のX方向に沿った入射角度は変化しないが、マイクロフライアイ6への入射光束のY方向に沿った入射角度は変化する。その結果、図2における各面光源31～34の中心31a～34aは、X方向には移動しないがZ方向に移動する。このように、V溝アキシコン10は、マイクロフライアイ6への入射光束のY方向に沿った入射角度を変化させるために入射光束の縦横比を変更する縦横比変更素子を構成している。

【0052】図4は、V溝アキシコンの間隔の変化、アフォーカルズームレンズの倍率の変化、およびズームレンズの焦点距離の変化が4極状の二次光源に及ぼす影響を模式的に説明する図である。図4(a)に示すように、V溝アキシコン10の間隔が零のとき、すなわち凹状屈折面10cと凸状屈折面10dとが互いに当接しているとき、4極状の二次光源を構成する各面光源はX方向およびZ方向に関して同じ位置関係に形成される。そして、V溝アキシコン10の間隔を零から所定の大きさに変化させると、図4(b)に示すように、各面光源はその形状および大きさを変えることなくZ方向に移動し、各面光源の中心のX方向に沿った間隔は変化しないがZ方向に沿った間隔は拡大する。

【0053】また、V溝アキシコン10の間隔が零の状態において、アフォーカルズームレンズ5の倍率の変化させると、図4(c)に示すように、各面光源はその形状および大きさを変えることなくX方向およびZ方向に同じ距離だけ移動し、各面光源の間隔は拡大または縮小する。さらに、V溝アキシコン10の間隔が零の状態において、ズームレンズ7の焦点距離の変化させると、図4(d)に示すように、4極状の二次光源の全体が相似的に拡大または縮小する。すなわち、各面光源はその形状を変えることなくその大きさが拡大または縮小するとともに、各面光源がX方向およびZ方向に同じ距離だけ移動する。なお、レーザー照射によるプリズム部材10aおよび10bの劣化を回避するために、アフォーカルズームレンズ5の光路中において4つの点像が形成される集光点から間隔を隔ててプリズム部材10aおよび10bを配置することが好ましい。

【0054】ところで、前述したように、回折光学素子4は、照明光路に対して挿脱自在に構成され、且つ輪帯照明用の回折光学素子4aや通常円形照明用の回折光学素子4bと切り換え可能に構成されている。以下、回折光学素子4に代えて回折光学素子4aを照明光路中に設定することによって得られる輪帯照明について簡単に説明する。

【0055】4極照明用の回折光学素子4に代えて輪帯照明用の回折光学素子4aを照明光路中に設定すると、回折光学素子4aを介して輪帯状の光束が形成される。回折光学素子4aを介して形成された輪帯状の光束は、アフォーカルズームレンズ5に入射し、瞳面にリング状の像(リング状の光源)を形成する。このリング状の像からの光は、ほぼ平行光束となってアフォーカルズームレンズ5から射出され、マイクロフライアイ6の後側焦点面に第1多数光源を形成する。

【0056】マイクロフライアイ6により形成された第1多数光源からの光束は、ズームレンズ7を介してフライアイレンズ8の入射面に、光軸AXを中心とした輪帯状の照野を形成する。その結果、フライアイレンズ8の後側焦点面には、入射面に形成された照野とほぼ同じ光強度を有する二次光源、すなわち光軸AXを中心とした輪帯状の二次光源が形成される。

【0057】図5は、V溝アキシコンの間隔の変化、アフォーカルズームレンズの倍率の変化、およびズームレンズの焦点距離の変化が輪帯状の二次光源に及ぼす影響を模式的に説明する図である。図5(a)に示すように、V溝アキシコン10の間隔が零のとき、すなわち凹状屈折面10cと凸状屈折面10dとが互いに当接しているとき、輪帯状の二次光源を構成する各面光源はX方向およびZ方向に関して同じ位置関係に形成される。そして、V溝アキシコン10の間隔を零から所定の大きさに変化させると、図5(b)に示すように、輪帯状の二次光源はその幅を変えることなく、輪帯状の二次光源の全体の大きさがZ方向に拡大し、Z方向に延びた楕円環

状の二次光源となる。

【0058】また、V溝アキシコン10の間隔が零の状態において、アフォーカルズームレンズ5の倍率の変化させると、図5(c)に示すように、輪帯状の二次光源はその幅を変えることなく、その外径(大きさ)が拡大または縮小する。さらに、V溝アキシコン10の間隔が零の状態において、ズームレンズ7の焦点距離の変化させると、図5(d)に示すように、輪帯状の二次光源の全体が相似的に拡大または縮小する。すなわち、輪帯状の二次光源の幅および外径がともに拡大または縮小する。

【0059】次いで、回折光学素子4または4aに代えて円形照明用の回折光学素子4bを照明光路中に設定することによって得られる通常円形照明について説明する。円形照明用の回折光学素子4bは、入射した矩形状の光束を円形状の光束に変換する機能を有する。したがって、回折光学素子4bにより形成された円形状の光束は、アフォーカルズームレンズ5によりその倍率に応じて拡大または縮小され、マイクロフライアイ6に入射する。

【0060】こうして、マイクロフライアイ6の後側焦点面には、第1多数光源が形成される。マイクロフライアイ6の後側焦点面に形成された第1多数光源からの光束は、ズームレンズ7を介して、フライアイレンズ8の入射面において光軸AXを中心とした円形状の照野を形成する。その結果、フライアイレンズ8の後側焦点面にも、光軸AXを中心とした円形状の二次光源が形成される。

【0061】この場合、V溝アキシコン10の間隔を零から所定の大きさに変化させると、円形状の二次光源はZ方向に拡大し、Z方向に延びた楕円状の二次光源となる。また、V溝アキシコン10の間隔が零の状態において、アフォーカルズームレンズ5の倍率の変化させるか、あるいはズームレンズ7の焦点距離の変化させると、円形状の二次光源の全体が相似的に拡大または縮小する。すなわち、円形状の二次光源の外径(大きさ)が拡大または縮小する。

【0062】以上のように、第1実施形態では、V溝アキシコン10の間隔を変化させることにより、二次光源の全体の大きさがX方向には変化することなくZ方向に変化する。その結果、マスクM上の直交する二方向(X方向およびY方向)で互いに異なる照明条件を実現することができ、ひいてはパターンに方向性があるマスクM上の直交する二方向で最適な照明条件を設定することができる。

【0063】なお、上述の説明では、図6(a)に示すように、V字状の凹状断面を有する第1プリズムとV字状の凸状断面を有する第2プリズムとでV溝アキシコン10を構成している。しかしながら、これに限定されることなく、図6(b)に示すように、V字状の凹状断面および凸状断面の頂点近傍を光軸AXに垂直な平面状に形成することもできる。また、輪帯照明または円形照明において外形が比較的円滑な楕円環状の二次光源または楕円状の二次光源を得るには、図6(c)に示すように、V字状の凹状断面および凸状断面の頂点近傍を円筒形状に形成することが好ましい。

【0064】また、上述の説明では、V溝アキシコン10の間隔を変化させることにより、二次光源の全体の大きさをX方向には変化させることなくZ方向に変化させている。しかしながら、図7(a)に示すように、V溝アキシコン10を光軸AXを中心として回転可能に構成することにより、二次光源の全体の大きさを所望の方向(たとえばX方向など)に変化させることもできる。

【0065】また、図7(b)に示すように、作用方向が互いに直交する2組のV溝アキシコンを配置することにより、二次光源の全体の大きさをX方向およびZ方向にそれぞれ独立に変化させることもできる。この場合、2組のV溝アキシコンを一体的にあるいは独立に光軸AXを中心として回転可能に構成することにより、二次光源の全体の大きさを任意の直交する二方向または任意の二方向にそれぞれ独立に変化させることもできる。

【0066】なお、上述の第1実施形態においては、光束変換素子としての回折光学素子4、4aおよび4bを、たとえばターレット方式で、あるいは公知のスライダ機構を利用して、照明光路中に位置決めするように構成することができる。

【0067】また、上述の第1実施形態では、マイクロフライアイ6を構成する微小レンズの形状を正六角形に設定している。これは、円形状の微小レンズでは、稠密に配列を行うことができず光量損失が発生するため、円形に近い多角形として正六角形を選定しているからである。しかしながら、マイクロフライアイ6を構成する各微小レンズの形状はこれに限定されることなく、たとえば矩形状を含む他の適当な形状を用いることができる。

【0068】さらに、上述の第1実施形態では、通常の円形照明を行う際に回折光学素子4bを照明光路中に位置決めしているが、この回折光学素子4bの使用を省略することもできる。また、上述の第1実施形態では、光束変換素子として回折光学素子を用いているが、これに限定されることなく、たとえばマイクロフライアイや微小プリズムアレイなどを用いることもできる。ところで、本発明で利用することのできる回折光学素子に関する詳細な説明は、米国特許第5,850,300号公報などに開示されている。

【0069】また、上述の第1実施形態においては、二次光源からの光をコンデンサー光学系9によって集光して重畳的にマスクMを照明する構成としているが、コンデンサー光学系9とマスクMとの間に、照明視野絞り(マスクブラインド)と、この照明視野絞りの像をマスクM上に形成するリレー光学系とを配置しても良い。こ

の場合、コンデンサー光学系９は、二次光源からの光を集光して重畳的に照明視野絞りを照明することになり、リレー光学系は、照明視野絞りの開口部（光透過部）の像をマスクＭ上に形成することになる。

【００７０】さらに、上述の第１実施形態においては、フライアイレンズ８を、複数の要素レンズを集積して形成しているが、これらをマイクロフライアイとすることも可能である。マイクロフライアイは、前述したように、光透過性基板にエッチングなどの手法により複数の微少レンズ面をマトリックス状に設けたものである。複数の光源像を形成する点に関して、フライアイレンズとマイクロフライアイとの間に機能上の差異は実質的には無いが、１つの要素レンズ（微少レンズ）の開口の大きさを極めて小さくできること、製造コストを大幅に削減できること、光軸方向の厚みを非常に薄くできることなどの点で、マイクロフライアイが有利である。

【００７１】図１０は、本発明の第２実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。第２実施形態は、第１実施形態と類似の構成を有するが、折り曲げミラー３とズームレンズ７との間の構成、フライアイレンズ８に代えてマイクロフライアイ（マイクロレンズアレイ）８ａが用いられていること、およびコンデンサー光学系９とマスクＭとの間の構成が第１実施形態と基本的に相違している。以下、第１実施形態との相違点に着目して、第２実施形態を説明する。なお、図１０では、照明光学装置が４極照明を行うように設定されている。

【００７２】第２実施形態では、光源１から射出されたほぼ平行光束が、ビームエキスパンダー２および折り曲げミラー３を介して、４極照明用の回折光学素子１１ａに入射する。回折光学素子１１ａは、矩形状の断面を有する平行光束が入射した場合、そのファーフィールド（フラウンホーファー回折領域）において４極状の光強度分布を形成する機能を有する。４極照明用の回折光学素子１１ａは、照明光路に対して挿脱自在に構成され、輪帯照明用の回折光学素子１１ｂや円形照明用の回折光学素子１１ｃと切り換え可能に構成されている。

【００７３】具体的には、回折光学素子１１ａは、光軸ＡＸに平行な所定の軸線回りに回転可能なターレット基板（回転板：図１０では不図示）上に支持されている。ターレット基板には、特性の異なる複数の４極照明用の回折光学素子１１ａ、特性の異なる複数の輪帯照明用の回折光学素子１１ｂ、および特性の異なる複数の円形照明用の回折光学素子１１ｃが円周方向に沿って設けられている。また、ターレット基板は、その中心点を通り光軸ＡＸに平行な軸線回りに回転可能に構成されている。

【００７４】したがって、ターレット基板を回転させることにより、多数の回折光学素子１１ａ～１１ｃから選択された所望の回折光学素子を照明光路中に位置決めすることができる。なお、ターレット基板の回転（ひいては回折光学素子１１ａと１１ｂと１１ｃとの間の切り換え）は、制御系２１からの指令に基づいて動作する駆動系２６により行われる。ただし、ターレット方式に限定されることなく、たとえば周知のスライド方式により回折光学素子１１ａと１１ｂと１１ｃとの間の切り換えを行うこともできる。

【００７５】光形状変換手段としての回折光学素子１１ａを介した光束は、アフォーカルレンズ（リレー光学系）１２に入射する。アフォーカルレンズ１２は、その前側焦点位置と回折光学素子１１ａの位置とがほぼ一致し且つその後側焦点位置と図中破線で示す所定面１３の位置とがほぼ一致するように設定されたアフォーカル系（無焦点光学系）である。ここで、所定面１３の位置は、第１実施形態においてマイクロフライアイ６が設置されている位置に対応している。

【００７６】したがって、回折光学素子１１ａに入射したほぼ平行光束は、アフォーカルレンズ１２の瞳面に４極状の光強度分布を形成した後、ほぼ平行光束となってアフォーカルレンズ１２から射出される。なお、アフォーカルレンズ１２の前側レンズ群１２ａと後側レンズ群１２ｂとの間の光路中には、光源側から順に、円錐アキシコン１４、第１Ｖ溝アキシコン１５、および第２Ｖ溝アキシコン１６が配置されているが、その詳細な構成および作用については後述する。以下、説明を簡単にするために、これらのアキシコン１４～１６の作用を無視して、第２実施形態の基本的な構成および作用を説明する。

【００７７】アフォーカルレンズ１２を介した光束は、σ値可変用のズームレンズ（変倍光学系）７を介して、オプティカルインテグレータとしてのマイクロフライアイ８ａに入射する。なお、σ値とは、投影光学系ＰＬの瞳の大きさ（直径）をＲ１とし、投影光学系ＰＬの瞳に形成される照明光束または光源像の大きさ（直径）をＲ２とし、投影光学系ＰＬのマスク（レチクル）Ｍ側の開口数をＮＡｏとし、マスク（レチクル）Ｍを照明する照明光学系の開口数をＮＡｉとするとき、σ＝ＮＡｉ／ＮＡｏ＝Ｒ２／Ｒ１として定義される。但し、輪帯照明の場合、Ｒ２は投影光学系ＰＬの瞳に形成される輪帯状の照明光束または輪帯状の光源像の外径であり、ＮＡｉは照明光学系の瞳に形成される輪帯光束の外径によって定められる開口数である。また、４極照明等の多極照明の場合、Ｒ２は投影光学系ＰＬの瞳に形成される多極状の照明光束または多極状の光源像に外接する円の大きさまたは直径であり、ＮＡｉは照明光学系の瞳に形成される多極状の照明光束に外接する円の大きさまたは直径によって定められる開口数である。また、輪帯照明の場合、輪帯比とは、輪帯状の照明光束の外径をＲｏ、輪帯状の照明光束の内径をＲｉとするとき、Ｒｉ／Ｒｏで定義される。

【００７８】なお、所定面１３の位置はズームレンズ７

の前側焦点位置の近傍に配置され、マイクロフライアイ８ａの入射面はズームレンズ７の後側焦点位置の近傍に配置されている。換言すると、ズームレンズ７は、所定面１３とマイクロフライアイ８ａの入射面とを実質的にフーリエ変換の関係に配置し、ひいてはアフォーカルレンズ１２の瞳面とマイクロフライアイ８ａの入射面とを光学的にほぼ共役に配置している。したがって、第１実施形態におけるフライアイレンズ８と同様の機能を有するマイクロフライアイ８ａの入射面上には、アフォーカルレンズ１２の瞳面と同様に、たとえば光軸ＡＸに対して偏心した４つの照野からなる４極状の照野を形成する。ここで、４極状の照野を構成する各照野の形状は回折光学素子１１ａの特性に依存するが、ここでは４つの円形状の照野からなる４極状の照野が形成されるものとする。この４極状の照野の全体形状は、ズームレンズ７の焦点距離に依存して相似的に変化する。

【００７９】マイクロフライアイ８ａを構成する各微小レンズは、マスクＭ上において形成すべき照野の形状（ひいてはウェハＷ上において形成すべき露光領域の形状）と相似な矩形状の断面を有する。マイクロフライアイ８ａに入射した光束は多数の微小レンズにより二次元的に分割され、その後側焦点面（ひいては照明光学系の瞳）にはマイクロフライアイ８ａへの入射光束によって形成される照野とほぼ同じ光強度分布を有する二次光源、すなわち光軸ＡＸに対して偏心した４つの円形状の実質的な面光源からなる４極状の二次光源が形成される。

【００８０】マイクロフライアイ８ａの後側焦点面に形成された４極状の二次光源からの光束は、コンデンサー光学系９の集光作用を受けた後、照明視野絞りとしてのマスクブラインド１７を重畳的に照明する。マスクブラインド１７の矩形状の開口部（光透過部）を介した光束は、結像光学系１８の集光作用を受けた後、マスクＭを重畳的に照明する。マスクＭのパターンを透過した光束は、投影光学系ＰＬを介して、ウェハＷ上にマスクパターンの像を形成する。投影光学系ＰＬの入射瞳面には投影光学系ＰＬの開口数を規定するための可変開口絞りが設けられ、この可変開口絞りの駆動は制御系２１からの指令に基づいて動作する駆動系２７により行われる。

【００８１】図１１は、第２実施形態においてアフォーカルレンズの前側レンズ群と後側レンズ群との間の光路中に配置された３つのアキシコン系（以下、単に「アキシコン」という）の構成を概略的に示す斜視図である。第２実施形態では、図１１に示すように、アフォーカルレンズ１２の前側レンズ群１２ａと後側レンズ群１２ｂとの間の光路中に、光源側から順に、円錐アキシコン１４、第１Ｖ溝アキシコン１５、および第２Ｖ溝アキシコン１６が配置されている。

【００８２】円錐アキシコン１４は、光源側から順に、光源側に平面を向け且つマスク側に凹円錐状の屈折面を向けた第１プリズム部材１４ａと、マスク側に平面を向け且つ光源側に凸円錐状の屈折面を向けた第２プリズム部材１４ｂとから構成されている。そして、第１プリズム部材１４ａの凹円錐状の屈折面と第２プリズム部材１４ｂの凸円錐状の屈折面とは、互いに当接可能なように相補的に形成されている。

【００８３】また、第１プリズム部材１４ａおよび第２プリズム部材１４ｂのうち少なくとも一方の部材が光軸ＡＸに沿って移動可能に構成され、第１プリズム部材１４ａの凹円錐状の屈折面と第２プリズム部材１４ｂの凸円錐状の屈折面との間隔が可変に構成されている。円錐アキシコン１４の間隔の変化は、制御系２１からの指令に基づいて動作する駆動系２８ａにより行われる。

【００８４】ここで、第１プリズム部材１４ａの凹円錐状屈折面と第２プリズム部材１４ｂの凸円錐状屈折面とが互いに当接している状態では、円錐アキシコン１４は平行平面板として機能し、形成される４極状の二次光源に及ぼす影響はない。しかしながら、第１プリズム部材１４ａの凹円錐状屈折面と第２プリズム部材１４ｂの凸円錐状屈折面とを離間させると、円錐アキシコン１４は、いわゆるビームエキスパンダーとして機能する。したがって、円錐アキシコン１４の間隔の変化に伴って、所定面１３への入射光束の角度は変化する。

【００８５】また、第１Ｖ溝アキシコン１５は、光源側に平面を向け且つマスク側に凹状で且つＶ字状の屈折面を向けた第１プリズム部材１５ａと、マスク側に平面を向け且つ光源側に凸状で且つＶ字状の屈折面を向けた第２プリズム部材１５ｂとから構成されている。第１プリズム部材１５ａの凹状屈折面は２つの平面から構成され、その交線はＺ方向に沿って延びている。第２プリズム部材１５ｂの凸状屈折面は、第１プリズム部材１５ａの凹状屈折面と互いに当接可能なように、換言すると第１プリズム部材１５ａの凹状屈折面と相補的に形成されている。

【００８６】すなわち、第２プリズム部材１５ｂの凸状屈折面も２つの平面から構成され、その交線はＺ方向に沿って延びている。また、第１プリズム部材１５ａおよび第２プリズム部材１５ｂのうち少なくとも一方が光軸ＡＸに沿って移動可能に構成され、第１プリズム部材１５ａの凹状屈折面と第２プリズム部材１５ｂの凸状屈折面との間隔が可変に構成されている。第１Ｖ溝アキシコン１５の間隔の変化は、制御系２１からの指令に基づいて動作する駆動系２８ｂにより行われる。

【００８７】さらに、第２Ｖ溝アキシコン１６は、光源側に平面を向け且つマスク側に凹状でＶ字状の屈折面を向けた第１プリズム部材１６ａと、マスク側に平面を向け且つ光源側に凸状で且つＶ字状の屈折面を向けた第２プリズム部材１６ｂとから構成されている。第１プリズム部材１６ａの凹状屈折面は２つの平面から構成され、その交線はＸ方向に沿って延びている。第２プリズム部

材１６ｂの凸状屈折面は、第１プリズム部材１６ａの凹状屈折面と相補的に形成されている。すなわち、第２プリズム部材１６ｂの凸状屈折面も２つの平面から構成され、その交線はX方向に沿って延びている。

【００８８】また、第１プリズム部材１６ａおよび第２プリズム部材１６ｂのうち少なくとも一方が光軸ＡＸに沿って移動可能に構成され、第１プリズム部材１６ａの凹状屈折面と第２プリズム部材１６ｂの凸状屈折面との間隔が可変に構成されている。第２Ｖ溝アキシコン１６の間隔の変化は、制御系２１からの指令に基づいて動作する駆動系２８ｃにより行われる。

【００８９】ここで、対向する凹状屈折面と凸状屈折面とが互いに当接している状態では、第１Ｖ溝アキシコン１５および第２Ｖ溝アキシコン１６は平行平面板として機能し、形成される４極状の二次光源に及ぼす影響はない。しかしながら、第１Ｖ溝アキシコン１５は、凹状屈折面と凸状屈折面とを離間させると、Ｚ方向に沿って平行平面板として機能するが、X方向に沿ってビームエキスパンダーとして機能する。また、第２Ｖ溝アキシコン１６は、凹状屈折面と凸状屈折面とを離間させると、X方向に沿って平行平面板として機能するが、Ｚ方向に沿ってビームエキスパンダーとして機能する。

【００９０】図１２は、第２実施形態の４極照明において形成される二次光源に対する円錐アキシコンの作用を説明する図である。第２実施形態の４極照明では、円錐アキシコン１４の間隔を零から所定の値まで拡大させることにより、４極状の二次光源を構成する円形状の各面光源４０ａ～４０ｄが光軸ＡＸを中心とした円の径方向に沿って外方へ移動するとともに、その形状が円形状から楕円形状に変化する。すなわち、変化前の円形状の各面光源４０ａ～４０ｄの中心点と変化後の楕円形状の各面光源４１ａ～４１ｄの中心点とを結ぶ線分は光軸ＡＸを通り、中心点の移動距離は円錐アキシコン１４の間隔に依存する。

【００９１】さらに、変化前の円形状の各面光源４０ａ～４０ｄを光軸ＡＸから見込む角度（光軸ＡＸから各面光源４０ａ～４０への一対の接線がなす角度）と、変化後の楕円形状の各面光源４１ａ～４１ｄを光軸ＡＸから見込む角度とが等しい。そして、変化前の円形状の各面光源４０ａ～４０ｄの直径と、変化後の楕円形状の各面光源４１ａ～４１ｄの光軸ＡＸを中心とした円の径方向に沿った短径とが等しい。なお、変化後の楕円形状の各面光源４１ａ～４１ｄの光軸ＡＸを中心とした円の周方向に沿った長径の大きさは、変化前の円形状の各面光源４０ａ～４０ｄの直径と円錐アキシコン１４の間隔とに依存する。

【００９２】したがって、円錐アキシコン１４の間隔を零から所定の値まで拡大させると、４つの円形状の面光源から構成される４極状の二次光源が、４つの楕円形状の面光源から構成される４極状の二次光源に変化し、変化前の二次光源の幅を変化させることなく、その外径および輪帯比を変更することができる。ここで、４極状の二次光源の幅は、４つの面光源に外接する円の直径すなわち外径と４つの面光源に内接する円の直径すなわち内径との差の１／２として規定される。また、４極状の二次光源の輪帯比は、外径に対する内径の比（内径／外径）として規定される。

【００９３】図１３は、第２実施形態の４極照明において形成される二次光源に対するズームレンズの作用を説明する図である。第２実施形態の４極照明では、ズームレンズ７の焦点距離が変化すると、４つの円形状の面光源４２ａ～４２ｄから構成される４極状の二次光源の全体形状が相似的に変化する。すなわち、４極状の二次光源を構成する円形状の各面光源４２ａ～４２ｄが、円形状を維持したまま光軸ＡＸを中心とした円の径方向に沿って移動する。

【００９４】そして、変化前の各面光源４２ａ～４２ｄの中心点と変化後の各面光源４３ａ～４３ｄの中心点とを結ぶ線分は光軸ＡＸを通り、中心点の移動距離および移動の向きはズームレンズ７の焦点距離の変化に依存する。また、変化前の各面光源４２ａ～４２ｄを光軸ＡＸから見込む角度と、変化後の各面光源４３ａ～４３ｄを光軸ＡＸから見込む角度とが等しい。こうして、ズームレンズ７の焦点距離を変化させることにより、４極状の二次光源の輪帯比を変化させることなくその外径だけを変更することができる。

【００９５】図１４は、第２実施形態の４極照明において形成される二次光源に対する第１Ｖ溝アキシコンおよび第２Ｖ溝アキシコンの作用を説明する図である。第１Ｖ溝アキシコン１５の間隔の変化に伴って、所定面１３への入射光束のＺ方向に沿った入射角度は変化しないが、所定面１３への入射光束のX方向に沿った入射角度は変化する。その結果、図１４（ａ）に示すように、４つの円形状の面光源４４ａ～４４ｄは、Ｚ方向には移動しないが、その形状および大きさを維持したままX方向に移動する。すなわち、第１Ｖ溝アキシコン１５の間隔が零から所定の値まで拡大すると、面光源４４ｂおよび４４ｃは－X方向に移動し、面光源４４ａおよび４４ｄは＋X方向に移動する。

【００９６】一方、第２Ｖ溝アキシコン１６の間隔の変化に伴って、所定面１３への入射光束のX方向に沿った入射角度は変化しないが、所定面１３への入射光束のＺ方向に沿った入射角度は変化する。その結果、図１４（ｂ）に示すように、４つの円形状の面光源４４ａ～４４ｄは、X方向には移動しないが、その形状および大きさを維持したままＺ方向に移動する。すなわち、第２Ｖ溝アキシコン１６の間隔が零から所定の値まで拡大すると、面光源４４ａおよび４４ｂは＋Ｚ方向に移動し、面光源４４ｃおよび４４ｄは－Ｚ方向に移動する。

【００９７】さらに、第１Ｖ溝アキシコン１５の間隔お

よび第２Ｖ溝アキシコン１６の間隔がともに変化すると、所定面１３への入射光束のＸ方向に沿った入射角度およびＺ方向に沿った入射角度はともに変化する。その結果、図１４（ｃ）に示すように、各面光源４４ａ～４４ｄは、その形状および大きさを維持したままＺ方向およびＸ方向に移動する。すなわち、第１Ｖ溝アキシコン１５の間隔および第２Ｖ溝アキシコン１６の間隔がともに零から所定の値まで拡大すると、面光源４４ａは＋Ｚ方向および＋Ｘ方向に移動し、面光源４４ｂは＋Ｚ方向および－Ｘ方向に移動し、面光源４４ｃは－Ｚ方向および－Ｘ方向に移動し、面光源４４ｄは－Ｚ方向および＋Ｘ方向に移動する。

【００９８】以上のように、円錐アキシコン１４は、照明光学系の瞳（マイクロフライアイ８ａの後側焦点面）での照明光の輪帯比を可変とする輪帯比可変手段を構成している。ズームレンズ7は、照明光学系の瞳での照明光の大きさを可変とする変倍光学系を構成している。第１Ｖ溝アキシコン１５は、照明光学系の瞳においてＸ方向に沿って光軸ＡＸを挟んで対称に照明光を変位させる第１変位手段を構成している。第２Ｖ溝アキシコン１６は、照明光学系の瞳においてＺ方向に沿って光軸ＡＸを挟んで対称に照明光を変位させる第２変位手段を構成している。そして、円錐アキシコン１４、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１６、およびズームレンズ7は、照明光学系の瞳での照明光の大きさおよび形状を可変とする可変手段を構成している。

【００９９】図１５は、第２実施形態の４極照明において形成される円形状の各面光源に対する円錐アキシコン、ズームレンズ、第１Ｖ溝アキシコンおよび第２Ｖ溝アキシコンの作用を説明する図である。図１５では、円錐アキシコン１４、第１Ｖ溝アキシコン１５および第２Ｖ溝アキシコン１６の間隔がともに零で且つズームレンズ7の焦点距離が最小値に設定された状態（以下、「標準状態」という）で形成される最も小さい４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４５ａに着目している。

【０１００】この標準状態で、第１Ｖ溝アキシコン１５の間隔を零から所定の値まで拡大させると、面光源４５ａはその形状および大きさを維持したままＸ方向に沿って移動し、参照符合４５ｂで示す位置に達する。次いで、第２Ｖ溝アキシコン１６の間隔を零から所定の値まで拡大させると、面光源４５ｂはその形状および大きさを維持したままＺ方向に沿って移動し、参照符合４５ｃで示す位置に達する。

【０１０１】また、ズームレンズ7の焦点距離を最小値から所定の値まで拡大させると、円形状の面光源４５ｃはその円形状を維持したまま拡大するとともに光軸ＡＸを中心とした円の径方向に沿って外方へ移動し、参照符合４５ｄで示す位置に達する。さらに、必要に応じて円錐アキシコン１４の間隔を零から所定の値まで拡大させると、円形状の面光源４５ｄは円形状から拡大した楕円形状へ変化するとともに光軸ＡＸを中心とした円の径方向に沿って外方へ移動し、参照符合４５ｅで示す位置に達する。

【０１０２】なお、第２Ｖ溝アキシコン１６の間隔を零から所定の値まで拡大させた後に第１Ｖ溝アキシコン１５の間隔を零から所定の値まで拡大させても、面光源４５ａはその形状および大きさを維持したまま参照符合４５ｃで示す位置に達する。同様に、最終的に得られる面光源の位置、形状および大きさは、円錐アキシコン１４、第１Ｖ溝アキシコン１５および第２Ｖ溝アキシコン１６の間隔の変化並びにズームレンズ7の焦点距離の変化に依存し、その変化の順序には依存しない。

【０１０３】こうして、円錐アキシコン１４、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１６およびズームレンズ7の作用により、４極状の二次光源を構成する各面光源の位置を広範囲に亘って移動させることができ、且つその形状および大きさを所定の範囲に亘って変化させることができる。しかしながら、実際には、円錐アキシコン１４や第１Ｖ溝アキシコン１５や第２Ｖ溝アキシコン１６による各面光源の移動比率（すなわち移動先の面光源の座標位置に対する移動元の面光源の座標位置）には光学設計上の制約があり、各面光源の移動範囲には制限がある。

【０１０４】そこで、第２実施形態では、４極照明用の回折光学素子１１ａとして、特性の異なる３種類の回折光学素子を備えている。図１６は、第２実施形態において特性の異なる３種類の４極照明用回折光学素子を介して形成される各面光源およびその移動範囲について説明する図である。図１６においても図１５と同様に、標準状態で形成される最も小さい４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４６に着目している。

【０１０５】第２実施形態では、第１の４極照明用回折光学素子により、４つの面光源の中心点を結んで形成される四角形がＸ方向に沿って細長い長方形になるような４極状の二次光源、すなわち図１４（ａ）の右側に示すような４極状の二次光源が形成される。第１の４極照明用回折光学素子を介して形成された４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４６ａは、第１Ｖ溝アキシコン１５および第２Ｖ溝アキシコン１６の作用により、参照符号４７ａで示す矩形状の範囲内で移動する。

【０１０６】一方、第２の４極照明用回折光学素子により、４つの面光源の中心点を結んで形成される四角形がＺ方向に沿って細長い長方形になるような４極状の二次光源、すなわち図１４（ｂ）の右側に示すような４極状の二次光源が形成される。第２の４極照明用回折光学素子を介して形成された４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４６ｂは、第１

V溝アキシコン１５および第２V溝アキシコン１６の作用により、参照符号４７ｂで示す矩形状の範囲内で移動する。

【０１０７】さらに、第3の４極照明用回折光学素子により、４つの面光源の中心点を結んで形成される四角形が正方形になるような４極状の二次光源、すなわち図１４（ｃ）の右側（あるいは図１４（ａ）～（ｃ）の左側）に示すような４極状の二次光源が形成される。第３の４極照明用回折光学素子を介して形成された４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４６ｃは、第１V溝アキシコン１５および第２V溝アキシコン１６の作用により、参照符号４７ｃで示す矩形状の範囲内で移動する。

【０１０８】こうして、第２実施形態では、第１V溝アキシコン１５や第２V溝アキシコン１６による各面光源の移動比率（ひいてはその移動範囲）が光学設計の観点からある程度制限される場合であっても、特性の異なる３種類の４極照明用回折光学素子を併用することにより、光軸ＡＸを中心とする円環状の領域において各面光源の位置を自在に移動させることができる。なお、図１６では図示を省略したが、円錐アキシコン１４およびズームレンズ7の作用により、光軸ＡＸを中心とする円環状の領域において、各面光源の位置、形状および大きさを所望の状態に適宜変更することもできる。

【０１０９】また、第２実施形態の第１変形例では、４極照明用の回折光学素子１１ａとして、特性の異なる４種類の回折光学素子を備えている。図１７および図１８は、第２実施形態の第１変形例において特性の異なる４種類の４極照明用回折光学素子を介して形成される各面光源並びにその移動および変形について説明する図である。図１７および図１８においても図１５および図１６と同様に、標準状態で形成される最も小さい４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源４８に着目している。

【０１１０】第２実施形態の第１変形例では、図１７および図１８に示すように、光軸ＡＸを中心とした円とＸ軸に平行な線分とＺ軸に平行な線分とで規定される四半円領域が光軸ＡＸを通る３つの線分によって４つの扇形領域に分割され、４種類の４極照明用回折光学素子によってそれぞれ形成される円形状の各面光源４８ａ～４８ｄの中心が各扇形領域内に位置するように設定されている。すなわち、第１の回折光学素子により面光源４８ａが形成され、第２の回折光学素子により面光源４８ｂが形成され、第3の回折光学素子により面光源４８ｃが形成され、第4の回折光学素子により面光源４８ｄが形成されるように設定されている。

【０１１１】以下、説明の簡単のために、四半円領域が４つの扇形領域に等分割され、各面光源４８ａ～４８ｄが互いに接するように光軸ＡＸを中心とした円の周方向に沿って配置されているものとする。この場合、円錐アキシコン１４の間隔を零から所定の値まで拡大させると、図１７に示すように、各面光源４８ａ～４８ｄはその形状が円形状から拡大した楕円形状へ変化するとともにその中心位置が光軸ＡＸを中心とした円の径方向に沿って外方へ移動し、それぞれ参照符合４９ａ～４９ｄで示す位置に達する。

【０１１２】また、ズームレンズ7の焦点距離を最小値から所定の値まで拡大させると、図１８に示すように、各面光源４８ａ～４８ｄはその円形状を維持したまま拡大するとともに、その中心位置が光軸ＡＸを中心とした円の径方向に沿って外方へ移動し、それぞれ参照符合５０ａ～５０ｄで示す位置に達する。こうして、第２実施形態の第１変形例では、特性の異なる４種類の４極照明用回折光学素子を併用することにより、光軸ＡＸを中心とする円環状の領域において各面光源の位置、形状および大きさを自在に変化させることができる。

【０１１３】なお、図１７および図１８では各面光源４８ａ～４８ｄが互いに接するように配置しているが、各面光源４８ａ～４８ｄが互いに間隔を隔てるように配置することもできる。いずれの場合も、円錐アキシコン１４、第１V溝アキシコン１５、第２V溝アキシコン１６およびズームレンズ7の作用により、光軸ＡＸを中心とする円環状の領域において、各面光源の位置、形状および大きさを所望の状態に適宜変更することができる。

【０１１４】さらに、第２実施形態の第２変形例では、４極照明用の回折光学素子１１ａとして、特性の異なる２種類の回折光学素子を備えている。図１９は、第２実施形態の第２変形例において特性の異なる２種類の４極照明用回折光学素子を介して形成される各面光源並びにその移動および変形について説明する図である。図１９においても図１５～図１８と同様に、標準状態で形成される最も小さい４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源５１に着目している。

【０１１５】第２実施形態の第２変形例では、一方の４極照明用回折光学素子により、４つの面光源の中心点を結んで形成される四角形がＸ方向に沿って細長い長方形になるような４極状の二次光源が形成される。一方の４極照明用回折光学素子を介して形成された４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源５１ａ（図１６の４６ａに対応）は、第１V溝アキシコン１５および第２V溝アキシコン１６の作用により、参照符号５２ａで示す矩形状の範囲内で移動する。

【０１１６】また、他方の４極照明用回折光学素子により、４つの面光源の中心点を結んで形成される四角形がＺ方向に沿って細長い長方形になるような４極状の二次光源が形成される。他方の４極照明用回折光学素子を介して形成された４極状の二次光源を構成する４つの円形状の面光源のうちの１つの面光源５１ｂ（図１６の４６ｂに対応）は、第１V溝アキシコン１５および第２V溝アキシコン１６の作用により、参照符号５２ｂで示す矩

形状の範囲内で移動する。

【0117】さらに、一方の4極照明用回折光学素子と第2V溝アキシコン16との併用により、あるいは他方の4極照明用回折光学素子と第1V溝アキシコン15との併用により、初期的な面光源51aと51bとの中間的な位置に面光源51cが形成される。この場合、面光源51cに対してズームレンズ7の変倍機能を作用させることにより、面光源51cはその円形状を維持したまま拡大するとともに、その中心位置が光軸AXを中心とした円の径方向に沿って外方へ移動し、参照符合51dで示す位置に達する。

【0118】あるいは、図示を省略したが、面光源51cに対して円錐アキシコン14を作用させることにより、面光源51cはその円形状が拡大した楕円形状へ変化するとともに、その中心位置が光軸AXを中心とした円の径方向に沿って外方へ移動する。こうして、第2実施形態の第2変形例では、特性の異なる2種類の4極照明用回折光学素子を併用することにより、光軸AXを中心とする円環状の領域において、各面光源の位置を自在に移動させることができる。また、一般的には、円錐アキシコン14、第1V溝アキシコン15、第2V溝アキシコン16およびズームレンズ7の作用により、光軸AXを中心とする円環状の領域において、各面光源の位置、形状および大きさを所望の状態に適宜変更することができる。

【0119】次に、4極照明用の回折光学素子11aに代えて輪帯照明用の回折光学素子11bを照明光路中に設定することによって得られる輪帯照明について簡単に説明する。この場合、回折光学素子11bに入射したほぼ平行光束は、アフォーカルレンズ12の瞳面に輪帯状の光強度分布を形成した後、ほぼ平行光束となってアフォーカルレンズ12から射出される。アフォーカルレンズ12を介した光束は、ズームレンズ7を介して、マイクロフライアイ8aの入射面に、光軸AXを中心とした輪帯状の照野を形成する。その結果、マイクロフライアイ8aの後側焦点面には、その入射光束によって形成される照野とほぼ同じ光強度分布を有する二次光源、すなわち光軸AXを中心とした輪帯状の二次光源が形成される。

【0120】図20は、第2実施形態の輪帯照明において形成される二次光源に対する円錐アキシコンの作用を説明する図である。第2実施形態の輪帯照明では、標準状態で形成された最も小さい輪帯状の二次光源60aが、円錐アキシコン14の間隔を零から所定の値まで拡大させることにより、その幅(外径と内径との差の1/2:図中矢印で示す)が変化することなく、その外径および内径がともに拡大された輪帯状の二次光源60bに変化する。換言すると、輪帯状の二次光源は、円錐アキシコン14の作用により、その幅が変化することなく、その輪帯比および大きさ(外径)がともに変化する。

【0121】図21は、第2実施形態の輪帯照明において形成される二次光源に対するズームレンズの作用を説明する図である。第2実施形態の輪帯照明では、標準状態で形成された輪帯状の二次光源60aが、ズームレンズ7の焦点距離を最小値から所定の値へ拡大させることにより、その全体形状が相似的に拡大された輪帯状の二次光源60cに変化する。換言すると、輪帯状の二次光源は、ズームレンズ7の作用により、その輪帯比が変化することなく、その幅および大きさ(外径)がともに変化する。

【0122】図22は、第2実施形態の輪帯照明において形成される二次光源に対する第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。上述したように、第1V溝アキシコン15の間隔の変化に伴って、所定面13への入射光束のZ方向に沿った入射角度は変化しないが、所定面13への入射光束のX方向に沿った入射角度は変化する。その結果、図22(a)に示すように、輪帯状の二次光源60aを構成する4つの四半円弧状の各面光源61〜64は、Z方向には移動しないがX方向に移動する。すなわち、第1V溝アキシコン15の間隔が零から所定の値に拡大すると、面光源61および63は−X方向に移動し、面光源62および64は+X方向に移動する。

【0123】一方、第2V溝アキシコン16の間隔の変化に伴って、所定面13への入射光束のX方向に沿った入射角度は変化しないが、所定面13への入射光束のZ方向に沿った入射角度は変化する。その結果、図22(b)に示すように、各面光源61〜64は、X方向には移動しないがZ方向に移動する。すなわち、第2V溝アキシコン16の間隔が零から所定の値に拡大すると、面光源61および62は+Z方向に移動し、面光源63および64は−Z方向に移動する。

【0124】さらに、第1V溝アキシコン15の間隔および第2V溝アキシコン16の間隔がともに変化すると、所定面13への入射光束のX方向に沿った入射角度およびZ方向に沿った入射角度はともに変化する。その結果、図22(c)に示すように、各面光源61〜64は、Z方向およびX方向に移動する。すなわち、第1V溝アキシコン15の間隔および第2V溝アキシコン16の間隔が零から所定の値に拡大すると、面光源61は+Z方向および−X方向に移動し、面光源62は+Z方向および+X方向に移動し、面光源63は−Z方向および−X方向に移動し、面光源64は−Z方向および+X方向に移動する。こうして、4つの独立した円弧状の面光源からなる4極状の二次光源を形成することができる。

【0125】以上、第2実施形態の輪帯照明における円錐アキシコン14、第1V溝アキシコン15、第2V溝アキシコン16およびズームレンズ7の作用を個別に説明したが、これらの光学部材の相互作用により様々な形態の輪帯照明が可能である。具体的には、図22(c)

に示す状態において、ズームレンズ7を作用させると、たとえば面光源62は、光軸AXを中心とした円の径方向に沿って移動し、その全体形状が相似的に変化した面光源62aに変化する。一方、図22（c）に示す状態において、円錐アキシコン14を作用させると、たとえば面光源64は光軸AXを中心とした円の径方向に沿って移動し、その径方向の寸法は変化することなくその周方向の寸法だけが変化した面光源64aに変化する。

【0126】しかしながら、実際には、光学設計上の制約により、円錐アキシコン14による輪帯比の変更範囲には制限がある。そこで、第2実施形態では、輪帯照明用の回折光学素子11bとして、特性の異なる2種類の回折光学素子を備えている。すなわち、第2実施形態では、一方の輪帯照明用回折光学素子により、たとえば0．5～0．68の範囲で輪帯比を変更するのに適した形状を有する輪帯状の二次光源を形成する。また、他方の輪帯照明用回折光学素子により、たとえば0．68～0．8の範囲で輪帯比を変更するのに適した形状を有する輪帯状の二次光源を形成する。その結果、2種類の輪帯照明用回折光学素子の併用により、0．5～0．8の範囲で輪帯比を変更することが可能になる。

【0127】ところで、図23（a）を参照すると、図22（a）または（b）の右側で得られる2極状の二次光源に外接する円（図中破線で示す）の曲率と各半円弧状の面光源の外側円弧の曲率とが一致しないことがわかる。そこで、第2実施形態の第3変形例では、第1V溝アキシコン15または第2V溝アキシコン16の作用によって得られる2極状の二次光源に外接する円の曲率と半円弧状の各面光源の外側円弧の曲率とを一致させるために、第3の輪帯照明用回折光学素子を付設している。第3の輪帯照明用回折光学素子は、図23（b）に示すように、光軸AXを中心とした2つの円によって規定されるような完全な輪帯状の二次光源ではなく、X方向またはZ方向に沿ってわずかに扁平な楕円環状の二次光源を形成する。

【0128】さらに詳細には、第3の輪帯照明用回折光学素子により形成される楕円環状の二次光源は一対の円弧状の面光源65aと65bとから構成され、各面光源65aおよび65bの外側円弧の曲率は第1V溝アキシコン15または第2V溝アキシコン16の作用によって得られる2極状の二次光源に外接する円の曲率と一致するように設定されている。したがって、第2実施形態の第3変形例では、第1V溝アキシコン15または第2V溝アキシコン16の作用によって得られる2極状の二次光源において、この2極状の二次光源に外接する円の曲率と、円弧状の各面光源各面光源65aおよび65bの外側円弧の曲率とが一致する。

【0129】さらに、4極照明用の回折光学素子11aまたは輪帯照明用の回折光学素子11bに代えて円形照明用の回折光学素子11cを照明光路中に設定することによって得られる通常の円形照明について簡単に説明する。この場合、回折光学素子11cに入射したほぼ平行光束は、アフォーカルレンズ12の瞳面に円形状の光強度分布を形成した後、ほぼ平行光束となってアフォーカルレンズ12から射出される。

【0130】アフォーカルレンズ12を介した光束は、ズームレンズ7を介して、マイクロフライアイ8aの入射面に、光軸AXを中心とした円形状の照野を形成する。その結果、マイクロフライアイ8aの後側焦点面（すなわち照明光学系の瞳）には、その入射光束によって形成される照野とほぼ同じ光強度分布を有する二次光源、すなわち光軸AXを中心とした円形状の二次光源が形成される。

【0131】第2実施形態の円形照明では、標準状態で形成された最も小さい円形状の二次光源が、ズームレンズ7の焦点距離を最小値から所定の値へ拡大させることにより、その全体形状が相似的に拡大された円形状の二次光源に変化する。換言すると、第2実施形態の円形照明では、ズームレンズ7の焦点距離を変化させることにより、円形状の二次光源の大きさ（外径）を変更することができる。

【0132】図24は、第2実施形態の円形照明において形成される二次光源に対する第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。第2実施形態の円形照明では、第1V溝アキシコン15の間隔が零から所定の値に拡大すると、図24（a）に示すように、円形状の二次光源を構成する4つの四半円状の面光源66a～66dのうち、面光源66aおよび66cは－X方向に移動し、面光源66bおよび66dは＋X方向に移動する。

【0133】一方、第2V溝アキシコン16の間隔が零から所定の値に拡大すると、図24（b）に示すように、面光源66aおよび66bは＋Z方向に移動し、面光源66cおよび66dは－Z方向に移動する。さらに、第1V溝アキシコン15の間隔および第2V溝アキシコン16の間隔がともに零から所定の値に拡大すると、図24（c）に示すように、面光源66aは＋Z方向および－X方向に移動し、面光源66bは＋Z方向および＋X方向に移動し、面光源66cは－Z方向および－X方向に移動し、面光源66dは－Z方向および＋X方向に移動する。こうして、4つの独立した4半円状の面光源からなる4極状の二次光源を形成することができる。

【0134】以上、第2実施形態の円形照明における第1V溝アキシコン15、第2V溝アキシコン16およびズームレンズ7の作用を個別に説明したが、これらの光学部材の相互作用により様々な形態の円形照明が可能である。しかしながら、実際には、光学設計上の制約により、ズームレンズ7による外径の変倍範囲には制限がある。そこで、第2実施形態では、円形照明用の回折光学

素子１１ｃとして、特性の異なる２種類の回折光学素子を備えている。

【０１３５】すなわち、第２実施形態では、一方の円形照明用回折光学素子により、比較的小さいσ値すなわち小σから中間的なσ値すなわち中σまでの範囲でσ値を変更するのに適した形状を有する円形状の二次光源を形成する。また、他方の円形照明用回折光学素子により、中σから比較的大きいσ値すなわち大σまでの範囲でσ値を変更するのに適した形状を有する円形状の二次光源を形成する。その結果、２種類の円形照明用回折光学素子の併用により、小σから大σまでの範囲（たとえば０．１≦σ≦０．９５）でσ値を変更することが可能になる。

【０１３６】以下、第２実施形態における照明条件の切り換え動作などについて具体的に説明する。まず、ステップ・アンド・リピート方式またはステップ・アンド・スキャン方式にしたがって順次露光すべき各種のマスクに関する情報などが、キーボードなどの入力手段２０を介して制御系２１に入力される。制御系２１は、各種のマスクに関する最適な線幅（解像度）、焦点深度等の情報を内部のメモリー部に記憶しており、入力手段２０からの入力に応答して駆動系２４、２６～２８に適当な制御信号を供給する。

【０１３７】すなわち、最適な解像度および焦点深度のもとで４極照明する場合、駆動系２６は制御系２１からの指令に基づいて４極照明用の回折光学素子１１ａを照明光路中に位置決めする。そして、所望の形態を有する４極状の二次光源を得るために、駆動系２８ａ～２８ｃは制御系２１からの指令に基づいてアキシコン１４～１６の間隔を設定し、駆動系２４は制御系２１からの指令に基づいてズームレンズ７の焦点距離を設定する。また、駆動系２７は、制御系２１からの指令に基づいて投影光学系ＰＬの可変開口絞りを駆動する。

【０１３８】さらに、必要に応じて、駆動系２８ａ～２８ｃによりアキシコン１４～１６の間隔を変化させたり、駆動系２４によりズームレンズ７の焦点距離を変化させたりすることにより、マイクロフライアイ８ａの後側焦点面に形成される４極状の二次光源の形態を適宜変更することができる。こうして、４極状の二次光源の全体の大きさ（外径）および形状（輪帯比）、各面光源の位置、形状、大きさなどを適宜変化させて、多様な４極照明を行うことができる。

【０１３９】また、最適な解像度および焦点深度のもとで輪帯照明する場合、駆動系２６は、制御系２１からの指令に基づいて、輪帯照明用の回折光学素子１１ｂを照明光路中に位置決めする。そして、所望の形態を有する輪帯状の二次光源を得るために、あるいは輪帯状の二次光源から派生的に得られる４極状の二次光源または２極状の二次光源を得るために、駆動系２８ａ～２８ｃは制御系２１からの指令に基づいてアキシコン１４～１６の間隔を設定し、駆動系２４は制御系２１からの指令に基づいてズームレンズ７の焦点距離を設定する。また、駆動系２７は、制御系２１からの指令に基づいて投影光学系ＰＬの可変開口絞りを駆動する。

【０１４０】さらに、必要に応じて、駆動系２８ａ～２８ｃによりアキシコン１４～１６の間隔を変化させたり、駆動系２４によりズームレンズ７の焦点距離を変化させたりすることにより、マイクロフライアイ８ａの後側焦点面に形成される輪帯状の二次光源の形態、あるいは派生的に得られる４極状の二次光源または２極状の二次光源の形態を適宜変更することができる。こうして、輪帯状の二次光源の全体の大きさ（外径）および形状（輪帯比）、派生的に得られる各面光源の位置、形状、大きさなどを適宜変化させて、多様な輪帯照明を行うことができる。

【０１４１】さらに、最適な解像度および焦点深度のもとで通常の円形照明をする場合、駆動系２６は、制御系２１からの指令に基づいて、円形照明用の回折光学素子１１ｃを照明光路中に位置決めする。そして、所望の形態を有する円形状の二次光源を得るために、あるいは円形状の二次光源から派生的に得られる４極状の二次光源または２極状の二次光源を得るために、駆動系２８ａ～２８ｃは制御系２１からの指令に基づいてアキシコン１４～１６の間隔を設定し、駆動系２４は制御系２１からの指令に基づいてズームレンズ７の焦点距離を設定する。また、駆動系２７は、制御系２１からの指令に基づいて投影光学系ＰＬの可変開口絞りを駆動する。

【０１４２】さらに、必要に応じて、駆動系２８ａ～２８ｃによりアキシコン１４～１６の間隔を変化させたり、駆動系２４によりズームレンズ７の焦点距離を変化させたりすることにより、マイクロフライアイ８ａの後側焦点面に形成される円形状の二次光源の形態、あるいは派生的に得られる４極状の二次光源または２極状の二次光源の形態を適宜変更することができる。こうして、円形状の二次光源の全体の大きさ（ひいてはσ値）、派生的に得られる各面光源の位置、形状、大きさなどを適宜変化させて、多様な円形照明を行うことができる。

【０１４３】なお、第２実施形態では、光源側から順に、円錐アキシコン１４と、第１Ｖ溝アキシコン１５と、第２Ｖ溝アキシコン１６とを配置しているが、この配置順序を適宜変化させることもできる。また、各アキシコン１４～１６では、光源側から順に、凹状の屈折面を有する第１プリズム部材と凸状の屈折面を有する第２プリズムとを配置しているが、この配置順序を逆にすることもできる。

【０１４４】また、第２実施形態では、各アキシコン１４～１６がそれぞれ一対のプリズム部材から構成されているが、これに限定されることなく、たとえば円錐アキシコン１４の第２プリズム部材１４ｂと第１Ｖ溝アキシコン１５の第１プリズム部材１５ａとを一体化したり、

第１Ｖ溝アキシコン１５の第２プリズム部材１５ｂと第２Ｖ溝アキシコン１６の第１プリズム部材１６ａとを一体化したりすることもできる。この場合、円錐アキシコン１４の第１プリズム部材１４ａ、一体化された２つのプリズム、および第２Ｖ溝アキシコン１６の第２プリズム部材１６ｂのうち少なくとも３つの部材を光軸ＡＸに沿って移動させることにより、各アキシコン１４～１６の間隔をそれぞれ独立に変化させることができる。

【０１４５】図２５は、本発明の第３実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。図２６は、第３実施形態においてアフォーカルレンズの光路中に配置された一対のＶ溝アキシコンの構成を概略的に示す斜視図である。第３実施形態は、第２実施形態と類似の構成を有する。しかしながら、第２実施形態ではアフォーカルレンズ１２の光路中に円錐アキシコンと一対のＶ溝アキシコンとが配置されているのに対し、第３実施形態では一対のＶ溝アキシコンだけが配置されている点が第２実施形態と基本的に相違している。以下、第２実施形態との相違点に着目して、第３実施形態を説明する。

【０１４６】第３実施形態の４極照明では、円錐アキシコンが配置されていないので、４極状の二次光源を構成する各面光源の円形状を楕円形状に変化させることはできない。しかしながら、複数の４極照明用回折光学素子１１ａを選択的に用いるとともに、第１Ｖ溝アキシコン１５および第２Ｖ溝アキシコン１６の作用を利用することにより、光軸ＡＸを中心とする円環状の領域において、各面光源の位置を適宜変更することができる。また、ズームレンズ７の変倍作用を補助的に利用することにより、光軸ＡＸを中心とする円環状の領域において、各面光源の位置および大きさを適宜変更することができる。

【０１４７】一方、第３実施形態の輪帯照明では、円錐アキシコンが配置されていないので、輪帯状の二次光源の輪帯比を連続的に変化させることはできない。しかしながら、複数の輪帯照明用回折光学素子１１ｂを選択的に用いるとともに、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１６およびズームレンズ７の作用を利用することにより、輪帯状の二次光源の全体的な大きさおよび形状（輪帯比）、あるいは輪帯状の二次光源から派生的に得られる２極状の二次光源または４極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１４８】ところで、円形照明では、円錐アキシコンの作用を積極的に利用することはない。したがって、第３実施形態の円形照明においても第２実施形態の場合と同様に、円形状の二次光源の全体的な大きさ、あるいは円形状の二次光源から派生的に得られる２極状の二次光源または４極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１４９】図２７は、本発明の第４実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。図２８は、第４実施形態においてアフォーカルレンズの光路中に配置された円錐アキシコンおよび第１Ｖ溝アキシコンの構成を概略的に示す斜視図である。第４実施形態は、第２実施形態と類似の構成を有する。しかしながら、第２実施形態ではアフォーカルレンズ１２の光路中に円錐アキシコンと一対のＶ溝アキシコンとが配置されているのに対し、第４実施形態では円錐アキシコンおよび第１Ｖ溝アキシコンだけが配置されている点が第２実施形態と基本的に相違している。以下、第２実施形態との相違点に着目して、第４実施形態を説明する。なお、図２７および図２８では、一方のＶ溝アキシコンとして第１Ｖ溝アキシコン１５を示しているが、一方のＶ溝アキシコンは第２Ｖ溝アキシコン１６であってもよい。

【０１５０】第４実施形態の４極照明では、一方のＶ溝アキシコン（１５または１６）しか配置されていないので、４極状の二次光源を構成する円形状の各面光源の形状および大きさを維持したままその位置だけを二次元的に変化させることはできない。しかしながら、複数の４極照明用回折光学素子１１ａを選択的に用いるとともに、円錐アキシコン１４、一方のＶ溝アキシコン（１５または１６）、およびズームレンズ７の作用を利用することにより、光軸ＡＸを中心とする円環状の領域において、各面光源の位置、形状および大きさを適宜変更することができる。

【０１５１】一方、第４実施形態の輪帯照明では、一方のＶ溝アキシコン（１５または１６）しか配置されていないので、輪帯状の二次光源から派生的に４極状の二次光源を得ることはできない。しかしながら、複数の輪帯照明用回折光学素子１１ｂを選択的に用いるとともに、円錐アキシコン１４、一方のＶ溝アキシコン（１５または１６）、およびズームレンズ７の作用を利用することにより、輪帯状の二次光源の全体的な大きさおよび形状（輪帯比）、あるいは輪帯状の二次光源から派生的に得られる２極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１５２】さらに、第４実施形態の円形照明では、一方のＶ溝アキシコン（１５または１６）しか配置されていないので、円形状の二次光源から派生的に４極状の二次光源を得ることはできない。しかしながら、複数の円形照明用回折光学素子１１ｃを選択的に用いるとともに、円錐アキシコン１４、一方のＶ溝アキシコン（１５または１６）、およびズームレンズ７の作用を利用することにより、円形状の二次光源の全体的な大きさ、あるいは円形状の二次光源から派生的に得られる２極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１５３】図２９は、本発明の第５実施形態にかかる

照明光学装置を備えた露光装置の構成を概略的に示す図である。第５実施形態は、第２実施形態と類似の構成を有する。しかしながら、第５実施形態では、波面分割型のオプティカルインテグレータ（マイクロフライアイ８ａ）に代えて、内面反射型のオプティカルインテグレータ（ロッド型インテグレータ７０）を用いている点が第２実施形態と基本的に相違している。以下、第２実施形態との相違点に着目して、第５実施形態を説明する。

【０１５４】第５実施形態では、マイクロフライアイ８ａに代えてロッド型インテグレータ７０を配置していることに対応して、回折光学素子１１とロッド型インテグレータ７０との間の光路中に、光源側から順に、ズームレンズ７１、第２回折光学素子（またはマイクロフライアイ）７２、およびインプットレンズ７３を配置している。また、照明視野絞りとしてのマスクブラインド１７は、ロッド型インテグレータ７０の射出面の近傍に配置されている。

【０１５５】ここで、ズームレンズ７１は、その前側焦点位置が回折光学素子１１の位置とほぼ一致し且つその後側焦点位置が第２回折光学素子７２の位置とほぼ一致するように配置されている。なお、ズームレンズ７１の焦点距離の変化は、制御系２１からの指令に基づいて動作する駆動系２９により行われる。また、インプットレンズ７３は、その前側焦点位置が第２回折光学素子７２の位置とほぼ一致し且つその後側焦点位置がロッド型インテグレータ７０の入射面の位置とほぼ一致するように配置されている。

【０１５６】ロッド型インテグレータ７０は、石英ガラスや蛍石のような硝子材料からなる内面反射型のガラスロッドであり、内部と外部との境界面すなわち内面での全反射を利用して集光点を通りロッド入射面に平行な面に沿って内面反射数に応じた数の光源像を形成する。ここで、形成される光源像のほとんどは虚像であるが、中心（集光点）の光源像のみが実像となる。すなわち、ロッド型インテグレータ７０に入射した光束は内面反射により角度方向に分割され、集光点を通りその入射面に平行な面に沿って多数の光源像からなる二次光源が形成される。

【０１５７】したがって、第５実施形態の４極照明（輪帯照明または円形照明）では、照明光路に選択的に設置された回折光学素子１１ａ（１１ｂまたは１１ｃ）を通過した光束が、ズームレンズ７１を介して、第２回折光学素子７２上に４極状（輪帯状または円形状）の照野を形成する。第２回折光学素子７２を通過した光束は、インプットレンズ７３を介して、ロッド型インテグレータ７０の入射面の近傍に集光する。図３０は、第５実施形態における第２回折光学素子の作用を説明する図である。

【０１５８】図３０（ａ）に示すように、第２回折光学素子７２が配置されていない場合、ズームレンズ７１およびインプットレンズ７３を介した光束が、ロッド型インテグレータ７０の入射面７０ａ上においてほぼ一点に集光する。その結果、ロッド型インテグレータ７０によりその入射側に形成される多数の光源が非常に散逸的になり（二次光源全体に対する各光源の充填率が小さくなり）、実質的な面光源を得ることができなくなってしまう。

【０１５９】そこで、第５実施形態では、光束発散素子としての第２回折光学素子７２をインプットレンズ７３の前側焦点位置の近傍に配置している。こうして、図３０（ｂ）に示すように、第２回折光学素子７２を介して発散された光束が、インプットレンズ７３を介して、ロッド型インテグレータ７０の入射面７０ａ上において所定の広がりをもって集光する。その結果、ロッド型インテグレータ７０によりその入射側に形成される多数の光源が非常に密実になり（二次光源全体に対する各光源の充填率が大きくなり）、実質的な面光源としての二次光源を得ることができる。

【０１６０】ロッド型インテグレータ７０によりその入射側に形成された４極状（輪帯状または円形状）の二次光源からの光束は、その射出面において重畳された後、マスクブラインド１７および結像光学系１８を介して、所定のパターンが形成されたマスクＭを照明する。なお、第５実施形態では、ズームレンズ７１の前側レンズ群７１ａと後側レンズ群７１ｂとの間の光路中に、光源側から順に、円錐アキシコン１４、第１Ｖ溝アキシコン１５、および第２Ｖ溝アキシコン１６が配置されている。

【０１６１】したがって、第５実施形態の４極照明においても第２実施形態と同様に、複数の４極照明用回折光学素子１１ａを選択的に用いるとともに、円錐アキシコン１４、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１６、およびズームレンズ７１の作用を利用することにより、光軸ＡＸを中心とする円環状の領域において、輪帯状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１６２】また、第５実施形態の輪帯照明においても第２実施形態と同様に、複数の輪帯照明用回折光学素子１１ｂを選択的に用いるとともに、円錐アキシコン１４、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１６、およびズームレンズ７１の作用を利用することにより、輪帯状の二次光源の全体的な大きさおよび形状（輪帯比）、あるいは輪帯状の二次光源から派生的に得られる２極状の二次光源または４極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【０１６３】さらに、第５実施形態の円形照明においても第２実施形態と同様に、複数の円形照明用回折光学素子１１ｃを選択的に用いるとともに、円錐アキシコン１４、第１Ｖ溝アキシコン１５、第２Ｖ溝アキシコン１

6、およびズームレンズ71の作用を利用することにより、円形状の二次光源の全体的な大きさ、あるいは円形状の二次光源から派生的に得られる2極状の二次光源または4極状の二次光源を構成する各面光源の位置、形状および大きさを適宜変更することができる。

【0164】以上のように、第2実施形態～第5実施形態においても、V溝アキシコン15または16の間隔を変化させることにより、二次光源の全体の大きさおよび形状がX方向またはZ方向に変化する。その結果、マスクM上の直交する二方向（X方向およびY方向）で互いに異なる照明条件を実現することができ、ひいてはパターンに方向性があるマスクM上の直交する二方向で最適な照明条件を設定することができる。

【0165】なお、上述の第2実施形態～第5実施形態のうち、可変手段として一対のV溝アキシコン15および16だけを備えた第3実施形態は、メモリー（DRAMなど）のリソグラフィー工程に特に好適である。また、可変手段として円錐アキシコン14と一方のV溝アキシコン（15または16）とだけを備えた第4実施形態は、ロジックデバイス（MPUなど）のリソグラフィー工程に特に好適である。さらに、可変手段として円錐アキシコン14と一対のV溝アキシコン15および16とを備えた第2実施形態および第5実施形態は、半導体デバイスを含む一般的なマイクロデバイスのリソグラフィー工程に好適である。

【0166】ところで、以上の第5実施形態（図29を参照）では、アキシコン系（14、15、16）のマスク側に配置されたオプティカルインテグレータを内面反射型オプティカルインテグレータ（ロッド型オプティカルインテグレータ）70とした例を説明したが、前述したオプティカルインテグレータとしてのフライアイレンズ8やマイクロフライアイ8aを内面反射型オプティカルインテグレータ（ロッド型オプティカルインテグレータ）70と置き換えることもできることは言うまでもない。

【0167】また、以上の第2実施形態、第3実施形態、および第5実施形態（図10、図25および図29を参照）では、第1V溝アキシコン15のV溝の方向をZ方向（0°方向）とし、第2V溝アキシコン16のV溝の方向をX方向（90°方向）とした例を示したが、本発明はこの配置に限定されるものではなく、例えば、第1V溝アキシコン15のV溝の方向を光軸中心に時計回りに45°回転した方向（45°方向）とし、第2V溝アキシコン16のV溝の方向を光軸中心に時計回りに45°回転した方向（135°方向）等にすることができる。これにより、マイクロフライアイ8aに入射する溝の影が斜めとなり照度むらを低減できる効果が期待できる。さらには、第1V溝アキシコン15のV溝の方向と第2V溝アキシコン16のV溝の方向とのなす角（交差角）を望まれる照明条件に応じて任意に変更することができる。以上の如く、2つのV溝アキシコンの溝の交差角を変更するには、制御系21は、入力手段20を介して入力された入力情報に基づいて駆動系28bと駆動系28cとの少なくとも一方を駆動させて、第1V溝アキシコン15と第2V溝アキシコン16とを光軸中心に相対的に回転させれば良い。

【0168】さらに、以上の第4実施形態（図27を参照）では、V溝アキシコン15のV溝の方向をZ方向（0°方向）とした例を示したが、本発明はこの配置に限定されるものではなく、例えば、V溝アキシコン15のV溝の方向を光軸中心に45°回転した方向（45°方向）、90°回転した方向（90°方向）、135°回転した方向（135°方向）等にすることができる。すなわち、V溝アキシコン15のV溝の方向を望まれる照明条件に応じて任意に変更することができる。以上の如く、V溝アキシコンの溝の方向を変更するには、制御系21は、入力手段20を介して入力された入力情報に基づいて駆動系28bを駆動させて、V溝アキシコン15を光軸中心に所定の回転量だけ回転させれば良い。

【0169】また、以上の各実施形態では、回折光学素子（11a，11b，11c）とσ値可変用のズームレンズ7（変倍光学系）との併用でσ値の可変範囲を0．1から0．95（0．1≦σ≦0．95）とすることが好ましいが、σ値可変用のズームレンズ7（変倍光学系）を構成するレンズ枚数やそれのスペース等の制約が解消されれば、装置として要求される0．1～0．95のσ値の範囲を連続的に可変とすることができる。

【0170】また、以上の第1実施形態～第5実施形態における輪帯照明において、照明光学系の瞳（投影光学系の瞳）に形成される輪帯光束は、0．4～0．95のσ値の範囲（0．4≦σ≦0．95）内で輪帯比を可変とすることが望ましい。さらに、以上の第1実施形態～第5実施形態における2極照明や4極照明を始めとした多極照明において、照明光学系の瞳（投影光学系の瞳）に形成される多極状光束は、0．4～0．95のσ値の範囲（0．4≦σ≦0．95）内で位置や大きさを可変とすることが望ましい。

【0171】さらに、また、以上の第1実施形態～第5実施形態において、投影光学系PLに残存する収差または経時的に変化する収差（波面収差等）を計測するために、例えば、米国特許第5，828，455号や米国特許第5，978，085号等に開示されている収差計測用マスク（収差計測用レチクル）をマスク（レチクル）Mを保持する不図示のマスクステージMSに載置し、その収差計測用マスクに対して適切な照明をすることによって、投影光学系PLの収差（波面収差等）を高精度に計測することが可能である。ここで、投影光学系PLの収差（波面収差等）を高精度に計測し得る照明条件をさまざまな角度から研究を進めてきた結果、照明光学系のσ値を0．01≦σ≦0．3の範囲の何れかに設定する

ことが好ましいことが判明した。さらに、投影光学系PLの収差(波面収差等)をより一層、高精度に計測するには、照明光学系のσ値を0.02≦σ≦0.2の範囲の何れかに設定することがより一層好ましい。このように、照明光学系のσ値を0.01≦σ≦0.3の範囲または0.02≦σ≦0.2の範囲に照明条件を設定するには、以上の各実施形態における照明条件設定手段(4a,4b,5,7,10,11a〜11c,12,14〜16,71,71a)の一部を構成する回折光学素子(11a,11b,11c)の代わりに、極小σ値を設定する計測用の回折光学素子を設定すれば良い。なお、以上の第1実施形態〜第5実施形態の投影光学系PLに収差が発生している場合には、計測された収差情報を入力手段20に入力し、制御系21は、例えば、入力手段20を介して入力された収差情報に基づいて不図示の駆動系を介して、投影光学系PLを構成する少なくとも1つの光学素子(レンズやミラー等)を移動(投影光学系PLの光軸方向の移動、光軸と直交する方向の移動、光軸に対して傾斜、光軸回りに回転)させることにより、投影光学系PLの収差を始めとした光学特性の悪化を補正することができる。

【0172】また、以上の第1実施形態〜第5実施形態に示した装置を走査型露光装置とした場合には、照明光学系はマスクM上にスリット状(短手方向と長手方向とを有する長方形状)の照明領域(図1、図10、図25、図27および図29の紙面方向又は走査方向に短手方向を有する照明領域)を、ウェハW上にスリット状の露光領域を形成し、不図示のマスクステージMSに保持されたマスクと、不図示のウェハステージ(基板ステージ)WSに保持されたウェハ(基板)とを走査方向(図1、図10、図25、図27および図29の紙面方向)に沿って反対向きへ移動させることにより、マスクMのパターン像が投影光学系PLを介してウェハW上に形成される。この場合、不図示のマスクステージMS及び不図示のウェハステージ(基板ステージ)WSは、不図示の各ステージを駆動させる駆動装置を介して制御系21によって制御される。

【0173】以上の各実施形態に示した装置において、オプティカルインテグレータとしてのフライアイレンズ(アレイ状光学素子)8やマイクロフライアイ(マイクロアレイ状光学素子)8aを構成する多数の光学素子(レンズ素子)の個々の断面形状は、マスクM上に形成されるスリット状(短手方向と長手方向とを有する長方形状)の照明領域、およびウェハW上に形成されるスリット状(短手方向と長手方向とを有する長方形状)の露光領域と相似とすることが好ましい。

【0174】また、以上の各実施形態に示した如く、オプティカルインテグレータとしてのフライアイレンズ(アレイ状光学素子)8やマイクロフライアイ(マイクロアレイ状光学素子)8aを内面反射型オプティカルインテグレータ(ロッド型オプティカルインテグレータ)に置き換えた走査型露光装置の場合、および第5実施形態の如くオプティカルインテグレータを内面反射型オプティカルインテグレータ(ロッド型オプティカルインテグレータ)とした走査型露光装置の場合、内面反射型オプティカルインテグレータ(ロッド型オプティカルインテグレータ)の断面形状は、マスクM上に形成されるスリット状(短手方向と長手方向とを有する長方形状)の照明領域、およびウェハW上に形成されるスリット状(短手方向と長手方向とを有する長方形状)の露光領域と相似とすることが好ましい。

【0175】なお、以上の各実施形態に示した装置を走査型露光装置とした場合、投影光学系PLの大型化及び複雑化を招くことなく効率良く広い視野を保ちながら、高いスループットのもとでの走査露光を達成するためには、マスクM上に形成されるスリット状の照明領域(またはウェハW上に形成されるスリット状の露光領域)における短手方向の長さをLsとし、その照明領域の長手方向の長さをLlとするとき、0.05<Ls/Ll<0.7の関係を満たすことが好ましい。以上の各実施形態に示した走査型露光装置では、例えば、Ls/Ll=1/3としている。

【0176】上述の各実施形態にかかる露光装置では、照明光学装置によってマスク(レチクル)を照明し(照明工程)、投影光学系を用いてマスクに形成された転写用のパターンを感光性基板に露光する(露光工程)ことにより、マイクロデバイス(半導体素子、撮像素子、液晶表示素子、薄膜磁気ヘッド等)を製造することができる。以下、上述の各実施形態の露光装置を用いて感光性基板としてのウェハ等に所定の回路パターンを形成することによって、マイクロデバイスとしての半導体デバイスを得る際の手法の一例につき図8のフローチャートを参照して説明する。

【0177】先ず、図8のステップ301において、1ロットのウェハ上に金属膜が蒸着される。次のステップ302において、その1ロットのウェハ上の金属膜上にフォトレジストが塗布される。その後、ステップ303において、上述の各実施形態の露光装置を用いて、マスク上のパターンの像がその投影光学系を介して、その1ロットのウェハ上の各ショット領域に順次露光転写される。その後、ステップ304において、その1ロットのウェハ上のフォトレジストの現像が行われた後、ステップ305において、その1ロットのウェハ上でレジストパターンをマスクとしてエッチングを行うことによって、マスク上のパターンに対応する回路パターンが、各ウェハ上の各ショット領域に形成される。その後、更に上のレイヤの回路パターンの形成等を行うことによって、半導体素子等のデバイスが製造される。上述の半導体デバイス製造方法によれば、極めて微細な回路パターンを有する半導体デバイスをスループット良く得ること

ができる。

【0178】また、上述の各実施形態の露光装置では、プレート（ガラス基板）上に所定のパターン（回路パターン、電極パターン等）を形成することによって、マイクロデバイスとしての液晶表示素子を得ることもできる。以下、図9のフローチャートを参照して、このときの手法の一例につき説明する。図9において、パターン形成工程４０１では、上述の各実施形態の露光装置を用いてマスクのパターンを感光性基板（レジストが塗布されたガラス基板等）に転写露光する、所謂光リソグラフィー工程が実行される。この光リソグラフィー工程によって、感光性基板上には多数の電極等を含む所定パターンが形成される。その後、露光された基板は、現像工程、エッチング工程、レチクル剥離工程等の各工程を経ることによって、基板上に所定のパターンが形成され、次のカラーフィルター形成工程４０２へ移行する。

【0179】次に、カラーフィルター形成工程４０２では、R（Red）、G（Green）、B（Blue）に対応した3つのドットの組がマトリックス状に多数配列されたり、またはR、G、Bの3本のストライプのフィルターの組を複数水平走査線方向に配列したカラーフィルターを形成する。そして、カラーフィルター形成工程４０２の後に、セル組み立て工程４０３が実行される。セル組み立て工程４０３では、パターン形成工程４０１にて得られた所定パターンを有する基板、およびカラーフィルター形成工程４０２にて得られたカラーフィルター等を用いて液晶パネル（液晶セル）を組み立てる。セル組み立て工程４０３では、例えば、パターン形成工程４０１にて得られた所定パターンを有する基板とカラーフィルター形成工程４０２にて得られたカラーフィルターとの間に液晶を注入して、液晶パネル（液晶セル）を製造する。

【0180】その後、モジュール組み立て工程４０４にて、組み立てられた液晶パネル（液晶セル）の表示動作を行わせる電気回路、バックライト等の各部品を取り付けて液晶表示素子として完成させる。上述の液晶表示素子の製造方法によれば、極めて微細な回路パターンを有する液晶表示素子をスループット良く得ることができる。

【0181】なお、上述の各実施形態では、変形照明において４極状や輪帯状の二次光源を例示的に形成しているが、光軸に対して偏心した２つの面光源からなる２極状二次光源や、光軸に対して偏心した８つの面光源からなる８極状の二次光源のような、いわゆる複数極状あるいは多極状の二次光源を形成することもできる。

【0182】また、上述の各実施形態では、照明光学装置を備えた投影露光装置を例にとって本発明を説明したが、マスク以外の被照射面を照明するための一般的な照明光学装置に本発明を適用することができることは明らかである。

【0183】

【発明の効果】以上説明したように、本発明の照明光学装置では、オプティカルインテグレータへの入射光束の所定方向に沿った入射角度を変化させるために、入射光束の縦横比を変更する縦横比変更素子を備えている。したがって、この縦横比変更素子の作用により、二次光源の全体の大きさを所定方向に沿って変化させることができ、ひいては被照射面上の直交する二方向で互いに異なる照明条件を実現することができる。

【0184】したがって、本発明の照明光学装置を組み込んだ露光装置では、パターンに方向性があるマスク上の直交する二方向で最適な照明条件を設定することができ、良好な照明条件のもとで良好なマイクロデバイスを製造することができる。さらに、また、本発明は、適切な照明条件のもとでマスクのパターンを正確に転写することができ、同時に、マスクのパターンを正確に転写するのに際して、投影光学系の光学性能を高精度で確認し得る露光装置や露光方法等を実現でき、さらには良好なるマイクロデバイスを製造することができる。

【図面の簡単な説明】

【図１】本発明の第１実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。

【図２】フライアイレンズの後側焦点面に形成される４極状の二次光源の構成を概略的に示す図である。

【図3】アフォーカルズームレンズの光路中に配置されたV溝アキシコンを構成する一対のプリズムの構成を概略的に示す図である。

【図4】V溝アキシコンの間隔の変化、アフォーカルズームレンズの倍率の変化、およびズームレンズの焦点距離の変化が４極状の二次光源に及ぼす影響を模式的に説明する図である。

【図5】V溝アキシコンの間隔の変化、アフォーカルズームレンズの倍率の変化、およびズームレンズの焦点距離の変化が輪帯状の二次光源に及ぼす影響を模式的に説明する図である。

【図6】V溝アキシコンの屈折面形状に関する変形例を示す図である。

【図7】V溝アキシコンの回転および組み合わせに関する変形例を示す図である。

【図8】マイクロデバイスとしての半導体デバイスを得る際の手法のフローチャートである。

【図9】マイクロデバイスとしての液晶表示素子を得る際の手法のフローチャートである。

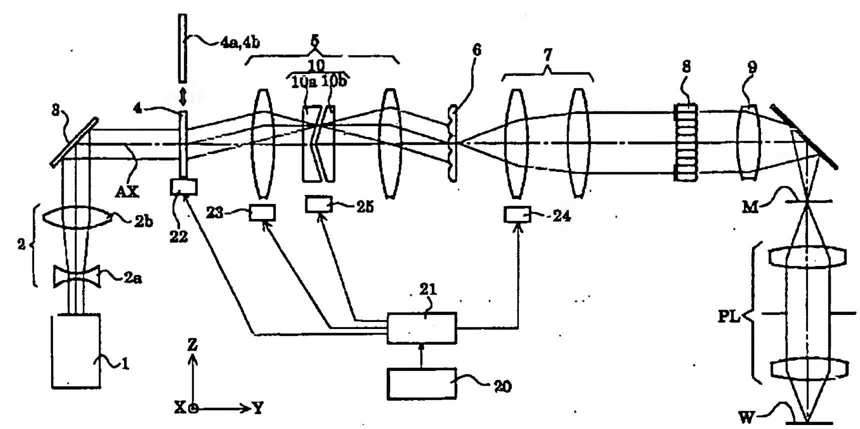
【図１０】本発明の第２実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。

【図１１】第２実施形態においてアフォーカルレンズの前側レンズ群と後側レンズ群との間の光路中に配置された３つのアキシコンの構成を概略的に示す斜視図である。

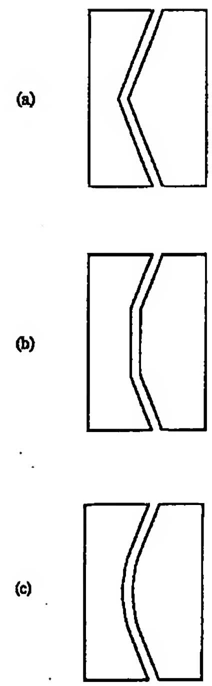
【図１２】第２実施形態の４極照明において形成される二次光源に対する円錐アキシコンの作用を説明する図で

ある。
【図13】第2実施形態の4極照明において形成される二次光源に対するズームレンズの作用を説明する図である。
【図14】第2実施形態の4極照明において形成される二次光源に対する第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。
【図15】第2実施形態の4極照明において形成される円形状の各面光源に対する円錐アキシコン、ズームレンズ、第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。
【図16】第2実施形態において特性の異なる3種類の4極照明用回折光学素子を介して形成される各面光源およびその移動範囲について説明する図である。
【図17】第2実施形態の第1変形例において特性の異なる4種類の4極照明用回折光学素子を介して形成される各面光源並びにその移動および変形について説明する図である。
【図18】第2実施形態の第1変形例において特性の異なる4種類の4極照明用回折光学素子を介して形成される各面光源並びにその移動および変形について説明する図である。
【図19】第2実施形態の第2変形例において特性の異なる2種類の4極照明用回折光学素子を介して形成される各面光源並びにその移動および変形について説明する図である。
【図20】第2実施形態の輪帯照明において形成される二次光源に対する円錐アキシコンの作用を説明する図である。
【図21】第2実施形態の輪帯照明において形成される二次光源に対するズームレンズの作用を説明する図である。
【図22】第2実施形態の輪帯照明において形成される二次光源に対する第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。
【図23】第2実施形態の第3変形例を説明する図である。
【図24】第2実施形態の円形照明において形成される二次光源に対する第1V溝アキシコンおよび第2V溝アキシコンの作用を説明する図である。
【図25】本発明の第3実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。
【図26】第3実施形態においてアフォーカルレンズの光路中に配置された一対のV溝アキシコンの構成を概略的に示す斜視図である。
【図27】本発明の第4実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。
【図28】第4実施形態においてアフォーカルレンズの光路中に配置された円錐アキシコンおよび第1V溝アキシコンの構成を概略的に示す斜視図である。
【図29】本発明の第5実施形態にかかる照明光学装置を備えた露光装置の構成を概略的に示す図である。
【図30】第5実施形態における第2回折光学素子の作用を説明する図である。
【符号の説明】
1　光源
4　回折光学素子
5　アフォーカルズームレンズ
6　マイクロフライアイ
7　ズームレンズ
8　フライアイレンズ
8a　マイクロフライアイ
9　コンデンサー光学系
10　V溝アキシコン
11，72　回折光学素子
12　アフォーカルレンズ
14　円錐アキシコン
15，16　V溝アキシコン
17　マスクブラインド
18　結像光学系
70　ロッド型インテグレータ
71　ズームレンズ
73　インプットレンズ
M　マスク
PL　投影光学系
W　ウェハ
20　入力手段
21　制御系
22～29　駆動系

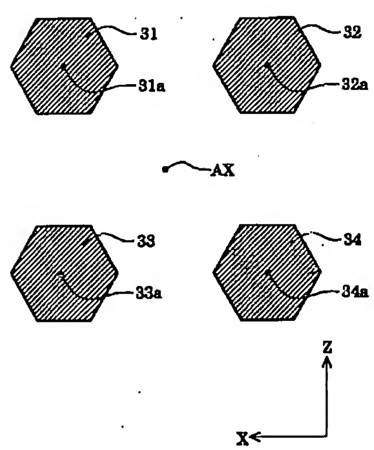
【図1】


4a,4b
5
10
10a 10b
6
7
8
9
3
4
AX
M
2b
2
2a
22
23
25
24
21
PL
1
Z
X
Y
20
W

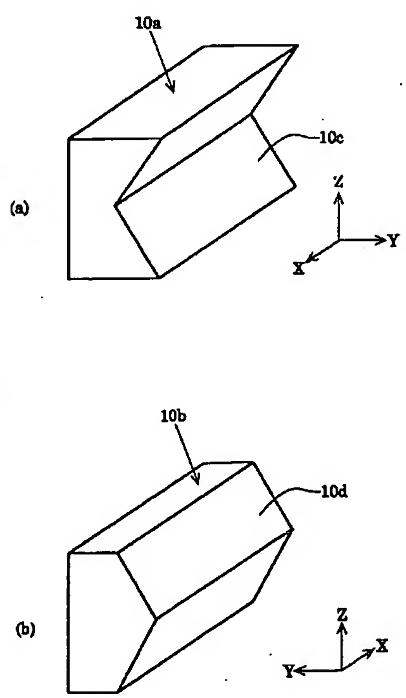
【図6】


(a)
(b)
(c)

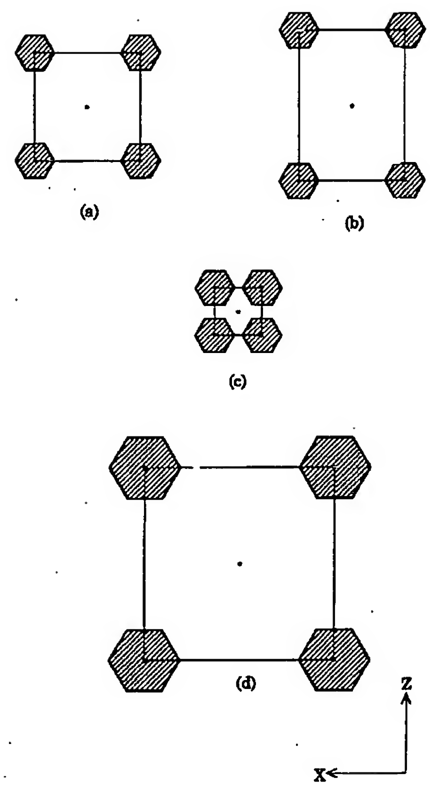
【図2】


31
31a
32
32a
AX
33
33a
34
34a
Z
X

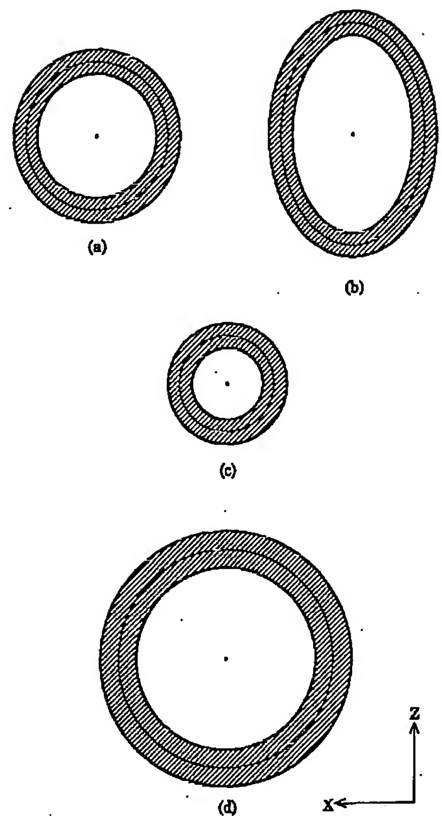
【図3】


10a
10c
(a)
Z
Y
X
10b
10d
(b)
Z
X
Y

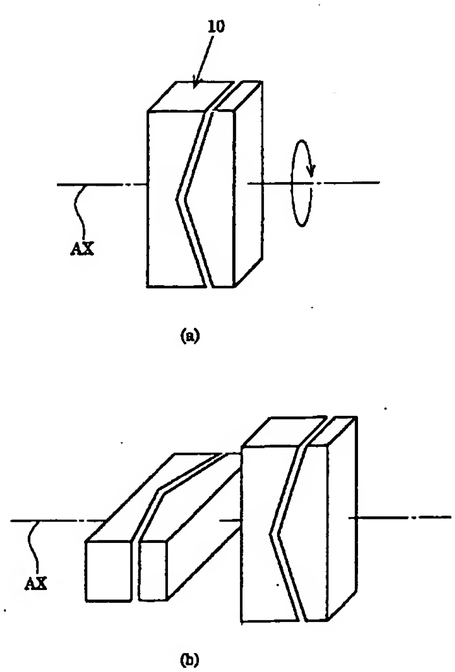
【図4】


(a)
(b)
(c)
(d)
Z
X

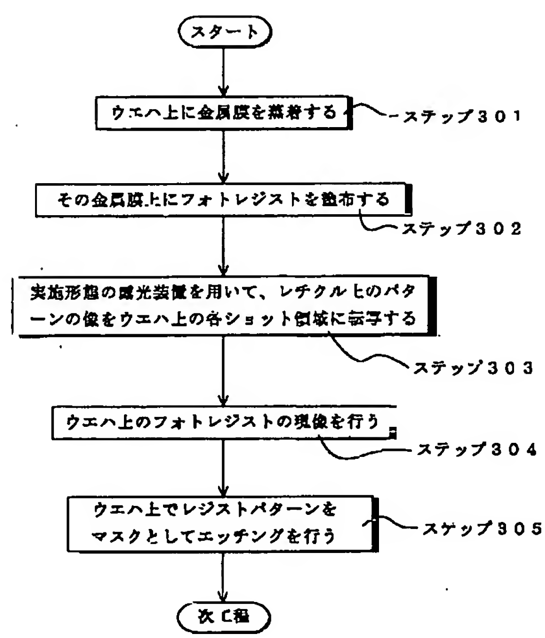
【図5】


(a)
(b)
(c)
(d)
Z
X

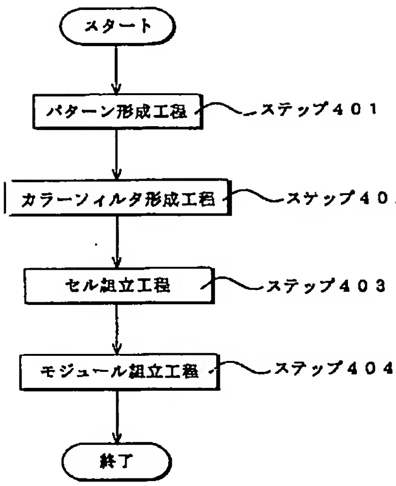
【図7】


10
AX
(a)
AX
(b)

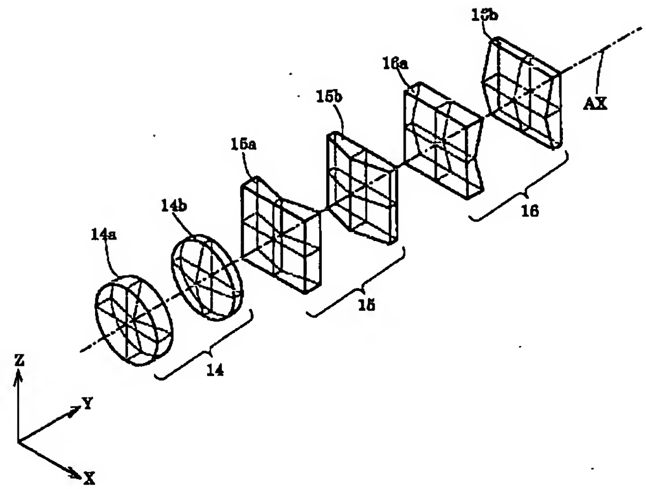
【図8】


スタート
ウエハ上に金属膜を蒸着する
ステップ301
その金属膜上にフォトレジストを塗布する
ステップ302
実施形態の露光装置を用いて、レチクル上のパターンの像をウエハ上の各ショット領域に転写する
ステップ303
ウエハ上のフォトレジストの現像を行う
ステップ304
ウエハ上でレジストパターンをマスクとしてエッチングを行う
ステップ305
次工程

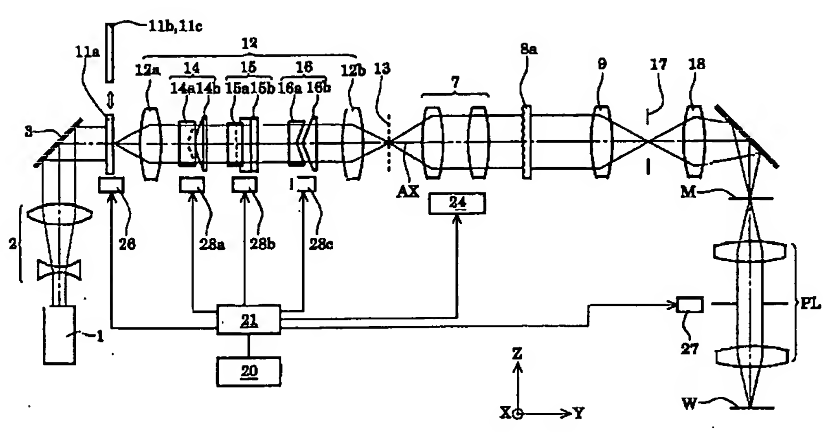
【図9】


スタート
パターン形成工程
ステップ４０１
カラーフィルタ形成工程
ステップ４０２
セル組立工程
ステップ４０３
モジュール組立工程
ステップ４０４
終了

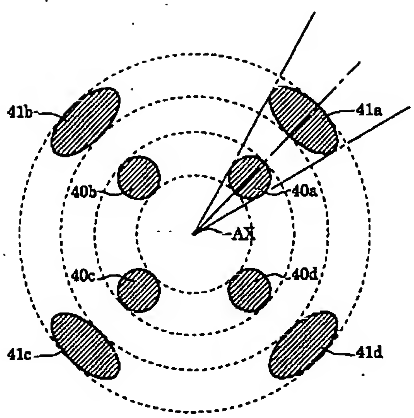
【図11】


16a
15b
15a
14b
14a
AX
16
15
14
Z
Y
X

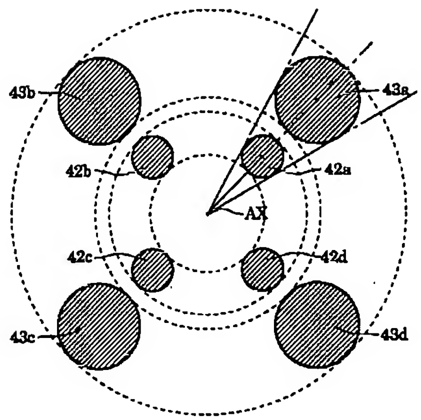
【図10】


11b,11c
11a
12
12a
14
14a14b
15
15a15b
16
16a 16b
12b
13
7
8a
9
17
18
3
AX
24
M
2
26
28a
28b
28c
21
PL
1
27
20
Z
X
Y
W

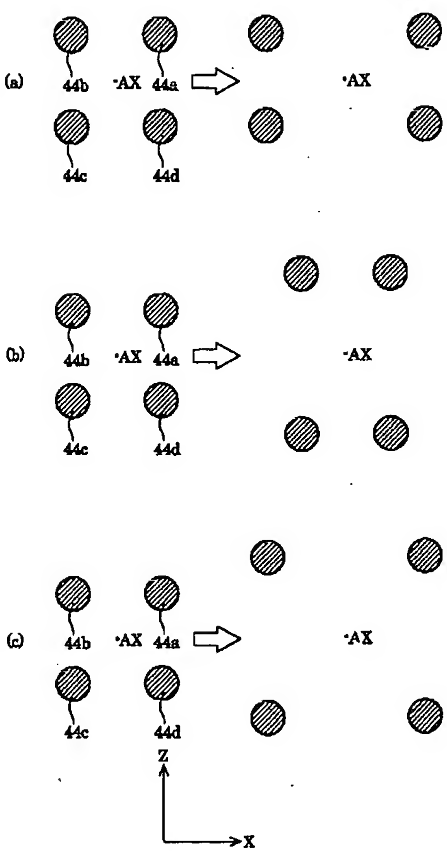
【図12】



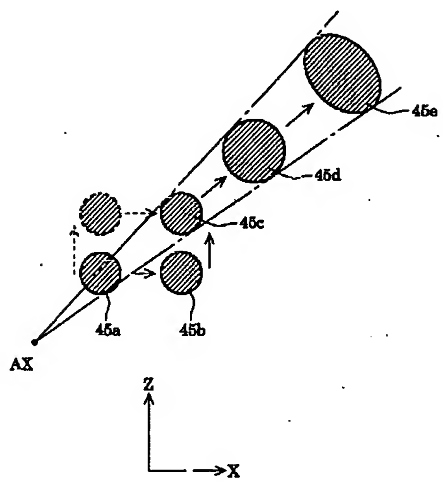
【図13】



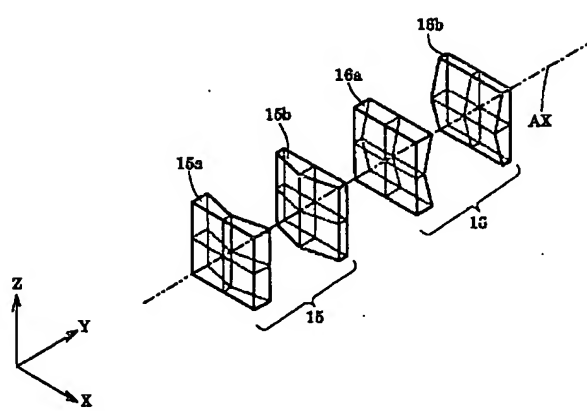
【図14】



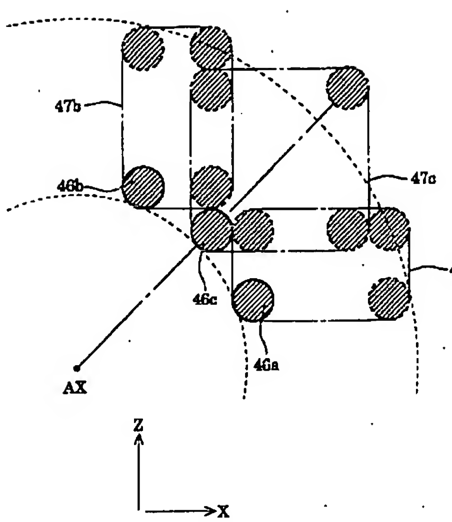
【図15】



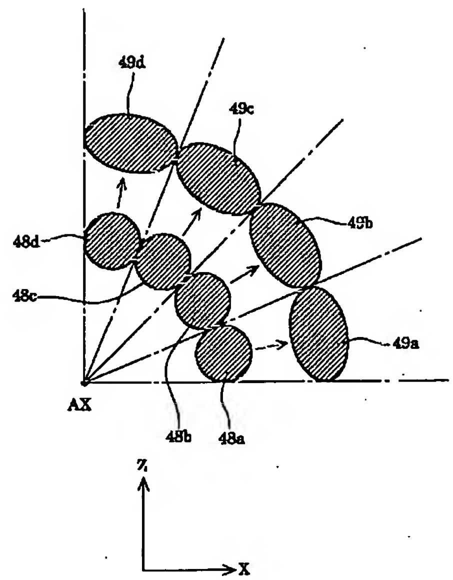
【図26】



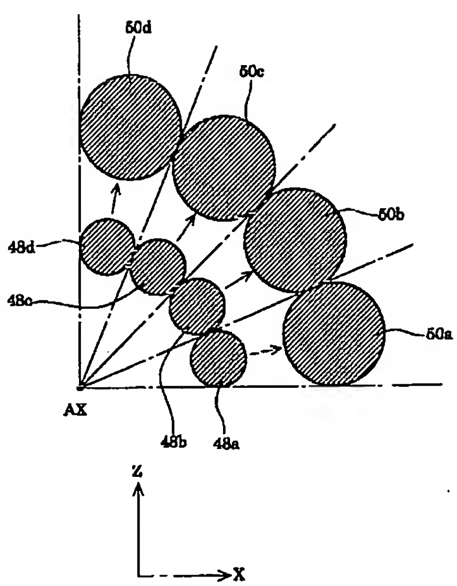
【図16】



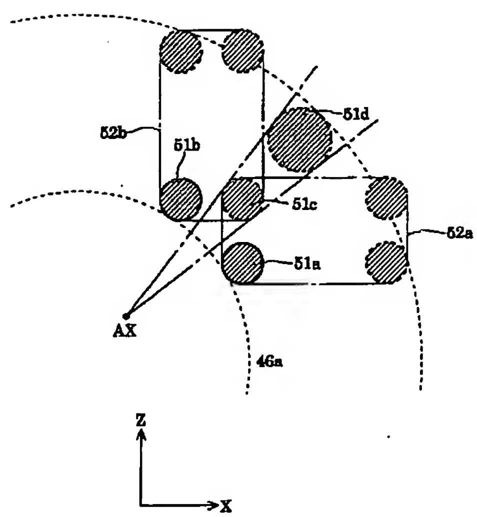
【図17】



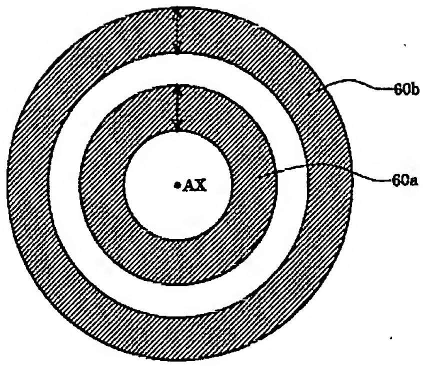
【図18】



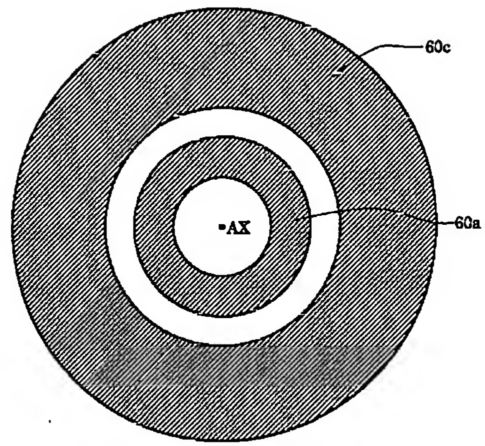
【図19】



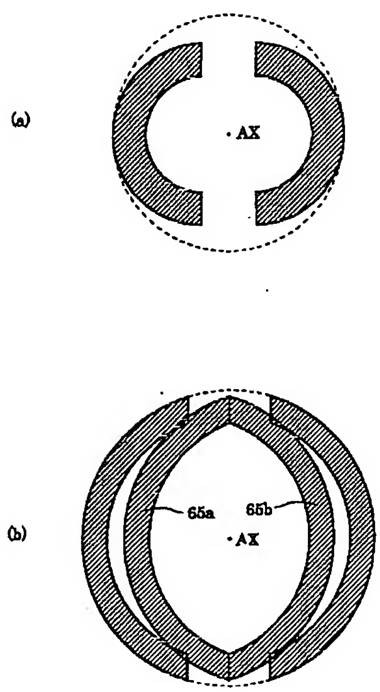
【図20】



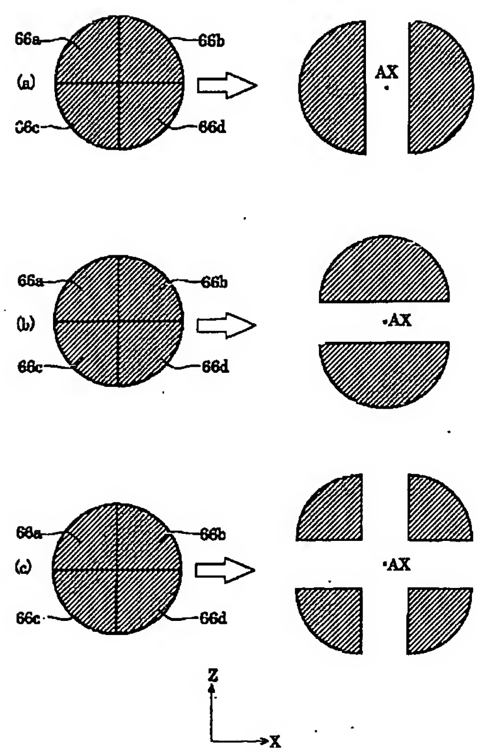
【図21】



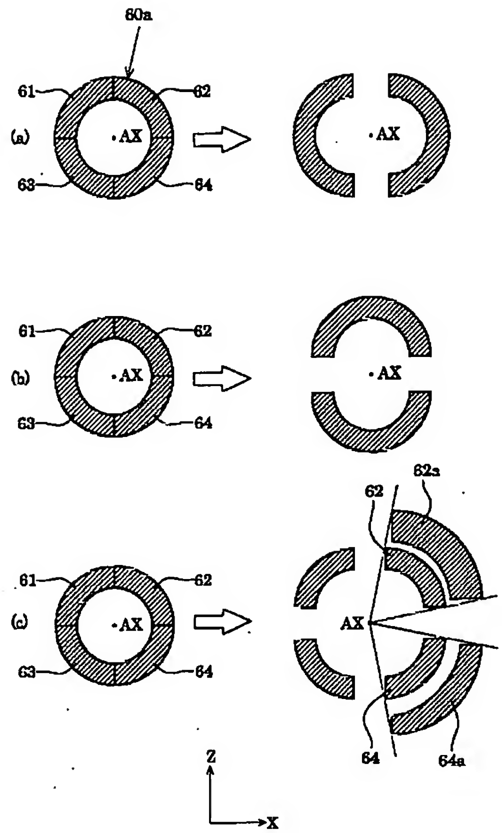
【図23】



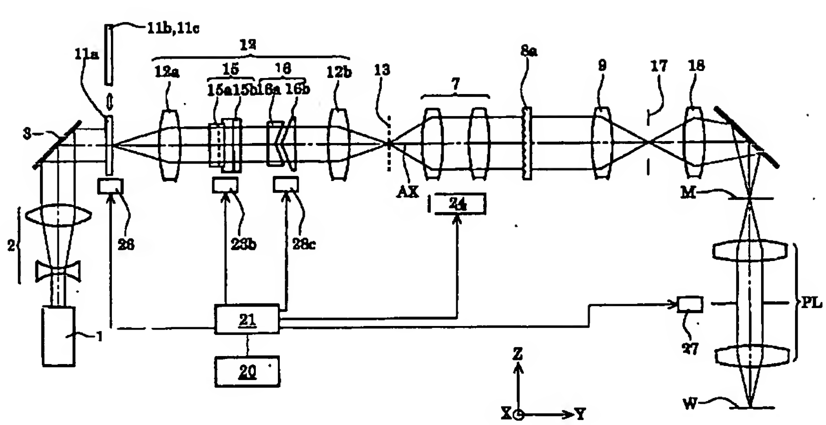
【図24】



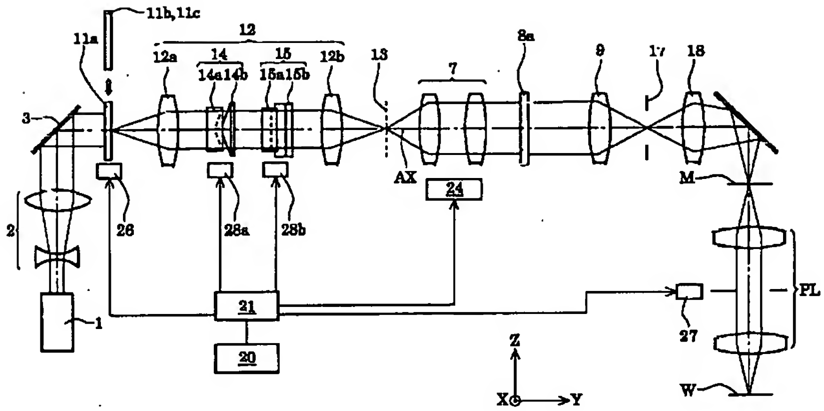
【図22】


60a
61
62
63
64
(a)
AX
(b)
(c)
62a
64a
Z
X

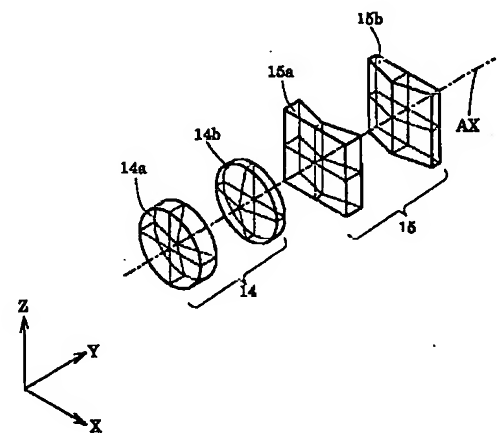
【図25】


11b,11c
11a
12
12a
15
15a
15b
16
16a
16b
12b
13
7
8a
9
17
18
3
AX
24
M
2
26
23b
28c
PL
21
1
27
20
Z
X
Y
W

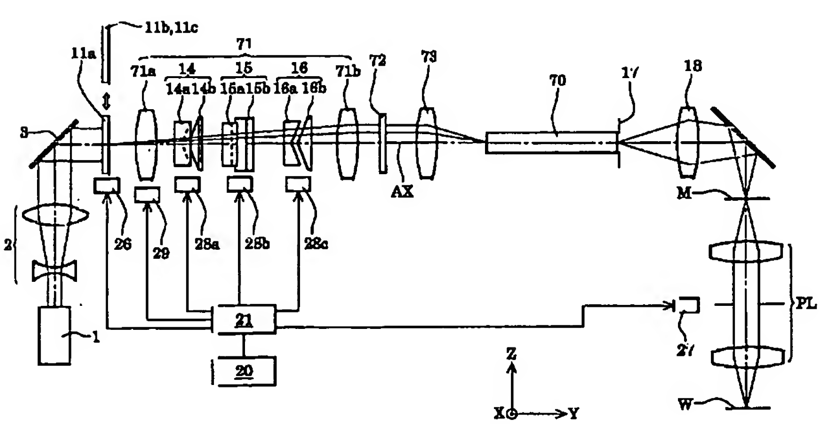
【図27】


11b,11c
11a
12
12a
14
14a14b
15
15a15b
12b
13
7
8a
9
17
18
3
26
28a
28b
AX
24
M
2
PL
21
1
27
20
Z
X
Y
W

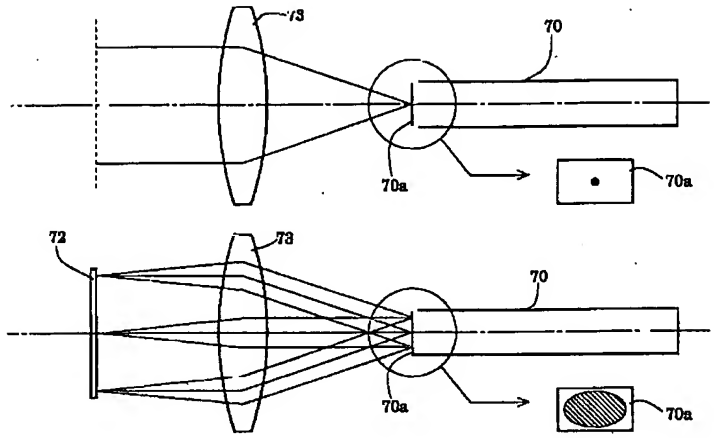
【図28】


15b
15a
AX
14b
14a
15
14
Z
Y
X

【図29】


11b,11c
71
11a
71a
14
14a14b
15
15a15b
16
16a 16b
71b
72
73
70
17
18
3
AX
M
26
29
28a
28b
28c
2
PL
21
1
27
20
Z
X
Y
W

【図30】



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2H052 BA02 BA03 BA09 BA12
5F046 BA04 BA05 CB10 CB12 CB13
CB23 DA01